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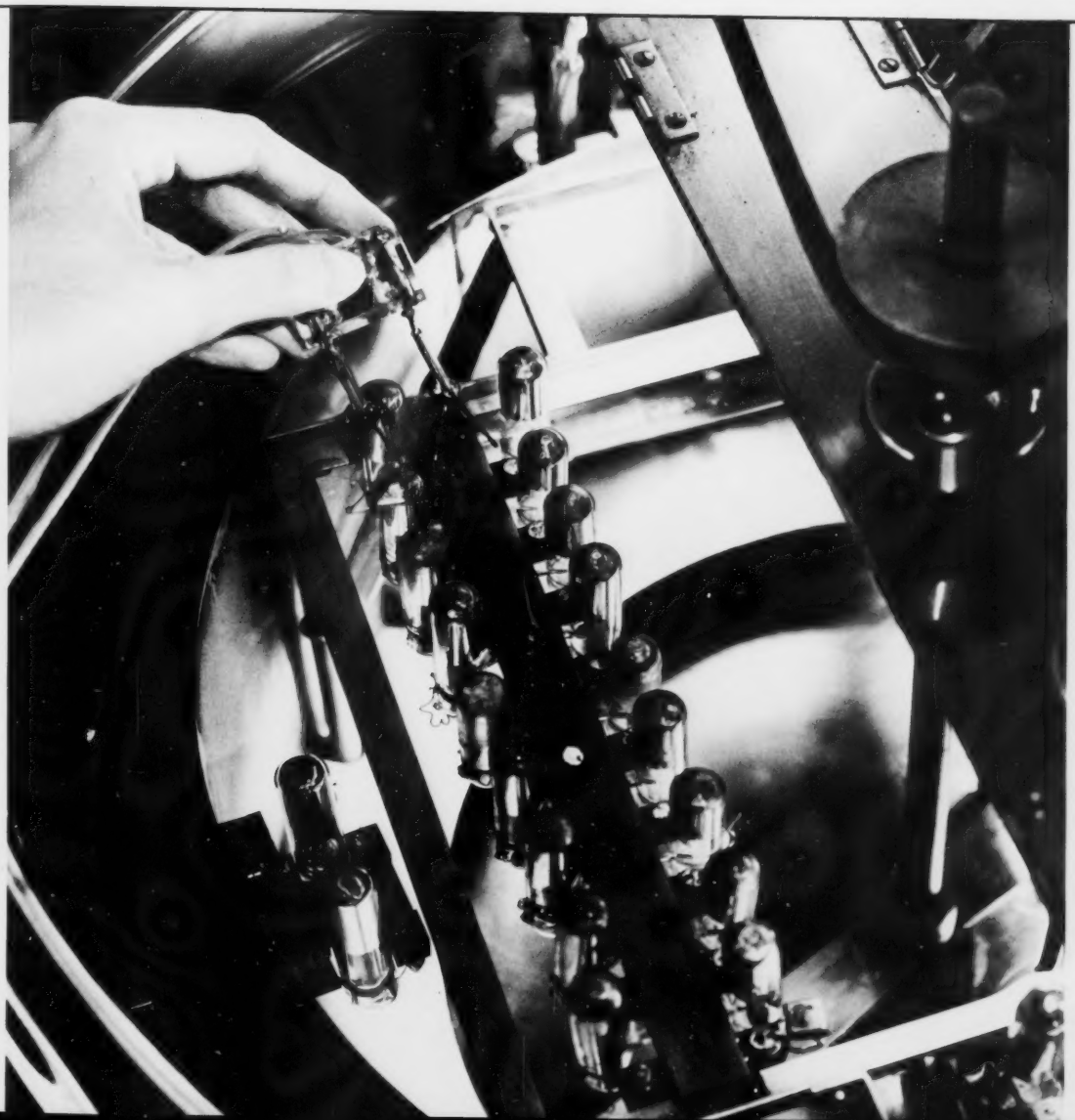

U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS
Technical News
BULLETIN

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Contents

COVER: The practical standard for d-c voltage is provided in this country by saturated standard cells forming National Reference Standards. These cells are extremely stable, but sensitive to change in temperature. Both the reference cells and cells sent to the Bureau for calibration are kept in a circulating oil bath that is electronically controlled to within a few thousandths of a degree of 28 °C. (See p. 132.)

FABRY-PEROT INTERFEROMETER
used as a dilatometer

A DILATOMETER which measures linear displacements as small as 10^{-7} cm has been devised by Virgil E. Bottom of the NBS Radio Standards Laboratory, Boulder, Colo. This instrument, based on the principle of the Fabry-Perot interferometer, is being used in studies of the static strain resulting from the magnetization of ferrites. It can also be used to determine the strains encountered in thermal expansions, the piezoelectric effect, or other phenomena in which the strains are similar in magnitude. Work on the dilatometer was sponsored jointly by the Army and the Navy.

A wide variety of techniques has been developed over the years to measure strains of small magnitude. These include mechanical and optical systems, strain gages, and capacitance-dependent devices. The interferometer has a great advantage over other systems in that no calibration is needed, as measurements are made directly in terms of a wavelength of light. The interferometer can be used either to measure strain directly, or, if this is inconvenient, to calibrate one of the other types of systems. Calibration of other systems without the use of an interferometer is usually quite difficult.

Interference is produced in the Fabry-Perot interferometer through the multiple reflection of light between two facing mirrors. The mirrors must be optically flat and adjusted so as to be accurately parallel. Some light passes through the reflective surface of the mirrors, and is brought to focus (on one side of the mirror arrangement) by an external lens. This arrangement produces a pattern of circular interference fringes, the fringes being bright and extremely sharp. The position of an individual fringe of such a pattern can be determined, with a micrometer eyepiece, to within one thousandth of the distance between fringes. It is this extreme sharpness of fringes which makes the Fabry-Perot interferometer so useful in measurements where the distances to be determined are quite small. Michelson or other similar interferometers are limited in that their fringes are less well-defined, making it difficult to determine fringe position to better than one tenth of the distance between fringes.

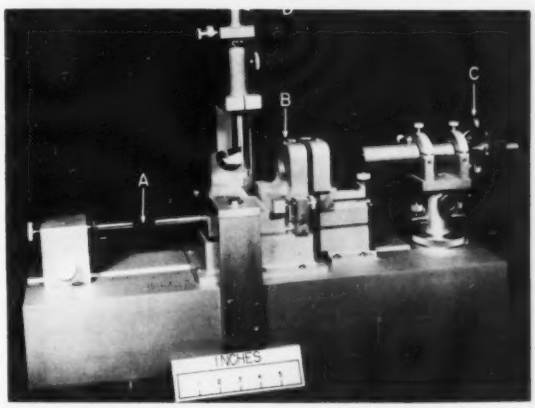
When the distance between the mirrors of a Fabry-Perot interferometer is decreased, the diameter of the fringes in the interference pattern decreases—the fringes appear to collapse towards the center. By measuring the diameter of two rings and the change in diameter of one of them, the change in distance between the mirrors can be calculated. Neither the distance between the mirrors (which is normally a few millimeters to a few centimeters), nor the focal length of the lens used to form the pattern need be known.

In the Bureau-developed interferometer, the specimen whose dimensional change is being determined is held firmly between an adjustable tailstock and a movable table on which is mounted one mirror of the interferometer. A telescope, having a micrometer eyepiece for the determination of the change in diameter of the fringes, is used to form the interference pattern. When a strain is induced in the specimen, the resultant movement of the mirror is detected as a change in diameter of one of the rings in the fringe pattern.

Using a mercury 198 light source, a mirror separation of 2.5 mm, and a telescope with a focal length of 25 cm, the magnification of the instrument is of the order of 10,000. For example, if the mirror moves 10^{-7} cm, the ring diameter changes by 10^{-3} cm, a change which can easily be measured. The actual sensitivity of the instrument is about 10^{-7} cm, as compared to the theoretical value of 2×10^{-8} cm. The difference between these values is probably due to deviations of the mirrors from perfect flatness.

Two precautions must be exercised in the design of a dilatometer of this type. First, provision must be made for control of the specimen temperature, as a change of but a few degrees will cause a change in length as great as that being measured. Second, the screw of the micrometer eyepiece must be uniform to ensure accurate determination of the fringe diameter.

A similar instrument has been developed by V. Arp and J. H. Wilson of the Cryogenic Engineering Laboratory for measurement of thermal expansivities. In this latter use the sample temperature is varied from 4° K to room temperature, while whole fringe changes are counted with a photocell circuit, and interpolation to fractions of a fringe is done as described above.



Dilatometer for the measurement of displacements as small as 10^{-7} cm. This device, based on the Fabry-Perot interferometer, is being used in studies of the static strain resulting from the magnetization of ferrites. In use, the specimen being measured is held at *A*, and its expansion transferred to mirror *B* of the etalon. The resulting change in fringe diameter, from which the linear displacement is calculated, is measured with telescope *C*. A mercury 198 light source is used. A microscope *D* is used for coarse observations of the location of the table.

a-c voltage calibrations

Eleventh of a Series on NBS Measurement Services*

AMONG THE THOUSANDS of instruments that are now required to measure accurately electrical quantities in science, industry, and defense activities, the voltmeter is probably the most common. The accuracy of all voltmeters used in this country depends ultimately on standardization and calibration services provided by NBS.

Direct-current voltages, common in automotive systems and electronic circuitry, are generally measured by permanent-magnet, moving-coil, d-c voltmeters, often preceded by a stable amplifier as in vacuum-tube voltmeters (VTVMs). Alternating voltages in power distribution circuits are usually measured by a-c (iron vane or electrodynamic) voltmeters or by d-c instruments having rectifiers to enable them to measure the a-c input as a d-c voltage. The usual a-c VTVM is a rectifying instrument and is perhaps the most often used voltage-measuring device.

The accuracy of an instrument can be determined by calibration—by comparing the indications of the working voltmeter with those of a reference voltmeter which has been selected for its accuracy and stability and has been calibrated against standards of voltage. Reference standards are maintained at the Bureau, commercial standards laboratories, and also at the laboratories of some users of calibration services, such as military organizations, universities, and manufacturers.

Calibration services offered by the Bureau are described in the NBS Test Fee Schedule.[1] Calibrations of saturated standard cells (d-c) and of voltage-measuring instruments from 20 c/s to 30 kc/s (a-c) are performed at the Bureau's Washington Laboratories. The NBS Boulder Laboratories perform similar calibrations, but at frequencies up to 1 Gc/s (1000 Mc/s).

In general, the Bureau restricts its calibration work to interlaboratory standards used as reference standards and high-precision instruments so that it can devote its resources more fully to the development of standards and techniques in today's critical measurement areas. It has encouraged the establishment of standards laboratories for the calibration of lower-echelon standards.

Thermal voltage converters are calibrated at radiofrequencies at consoles like this at the NBS Boulder Laboratories. The console has two calibrating positions at each of which two of the console's four fixed frequencies are available. The connectors on the work surface lead to the a-c–d-c transfer standards below.

The Standard Cell

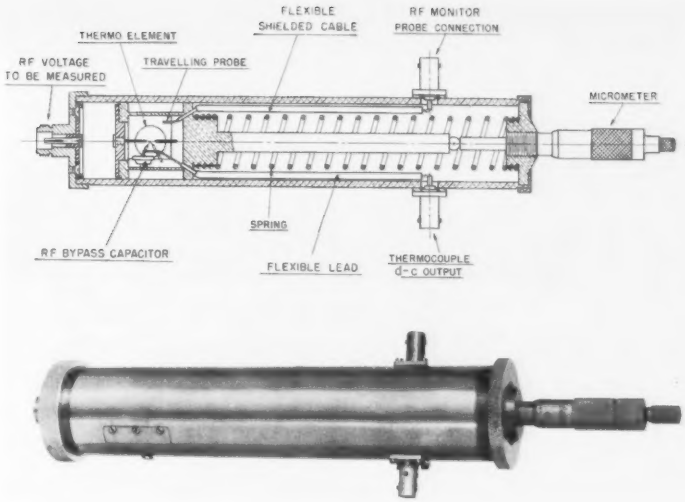
Electrical units are determined at intervals by national laboratories in terms of length, mass, and time by experimental procedures known as absolute determinations. An accurately known resistor and an accurately known direct current are used to establish the volt. Between these absolute determinations a group of standard cells is used to maintain the National volt. Working standard saturated cells are used in both the Boulder and Washington laboratories for measuring standard cells submitted for calibration. The working standards are accurately known in terms of the national reference standard of voltage through frequent intercomparisons.

The Bureau calibrates saturated standard cells sent to it to an accuracy of ± 0.0002 percent or better.[2] Such accuracy is made possible by extreme care in use of the cells and by maintaining the standards and cells submitted for calibration in oil or air baths thermostatically controlled to within a few thousandths of a degree Celsius.

Direct-current voltages are accurately measured by the use of a potentiometer and its accessory equipment, a standard cell, and a voltbox. Laboratories requiring high accuracy in d-c voltage measurements can obtain

In title: **A 1-v rms alternating voltage with a sine-wave form is compared with positive and negative 1-v d-c levels, shown as dotted lines.**

**Previous articles have been:* Calibration of gage blocks, *Feb. 1961*; Thermocouple calibrations, *Mar. 1961*; Calibration of platinum resistance thermometers, *Apr. 1961*; Calibration of inductive voltage dividers, *May 1961*; X- and gamma-ray calibration, *July 1961*; Calibration of microphones, *Nov. 1961*; Calibration of optical pyrometers, *Nov. 1961*; Calibration of flowmeters for liquid hydrocarbons, *Feb. 1962*; Calibration of neutron sources, *Mar. 1962*; *and* Precision resistance measurement, *Feb. 1963*.



The piston of the AT voltmeter carries a small thermal converter and RF probe; micrometer control of piston position makes possible precise and reproducible attenuation settings over a wide voltage range. This NBS-developed device is extremely stable, varying less than 1 percent over a year's time.

it by use of a potentiometer which is frequently referred to the emf of a standard cell; this method is preferable to use of a calibrated meter.

A-C Voltage

Alternating-current and voltage can be defined in terms of the d-c units—one volt rms (root-mean-square), the common a-c measure, is a periodically varying potential (not necessarily sinusoidal) that can do the same amount of work in a resistive circuit as 1 volt d-c.

Most VTVMs used for a-c measurements actually respond to the average or peak value of the rectified a-c voltage, indicating on scales marked in rms volts. Such instruments could give correct indications for sinusoidal alternating currents and voltages, but perfectly sinusoidal waveforms are seldom found in distribution lines or in electronic equipment.

Some voltmeters indicate values of rms voltage independently of waveform; electrodynamic voltmeters do so with an accuracy better than ± 0.1 percent at power frequencies within a limited frequency range.[3] Electrostatic voltmeters are in general insensitive to waveform distortion, but do not have suitable voltage ranges for general-purpose use. Electrothermal devices (in which the heat generated by the alternating current produces a d-c voltage which is measured) can be used over a wide frequency range, but have poor long-term stability and, in addition, all the inaccuracies of the indicating device. Most of the a-c measurements, however, are made by means of fundamentally less suitable, but cheaper, meters indicating average or peak rectified voltage.

Transfer Instruments

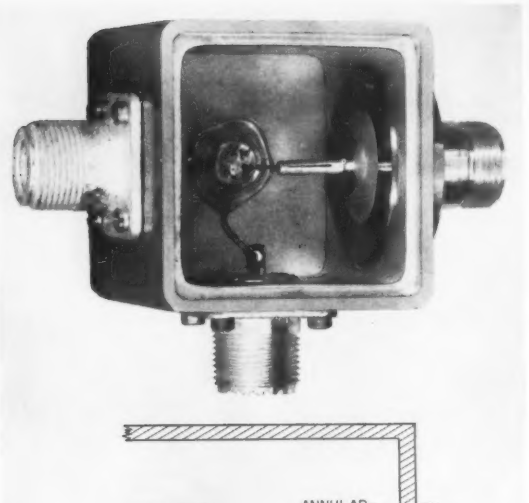
The shortcomings of a-c measuring instruments have led to the use of transfer instruments (which give the same response for equal a-c and d-c voltages) for a-c calibrations. Such a device is used by measuring the d-c potential that produces the same effect as the a-c voltage being measured. All true rms types of instruments can be used to make d-c measurements, but of the three types, only electrothermal devices are now in wide use as transfer instruments for a-c calibrations.

One type of transfer instrument, the thermoelement or thermal converter, consists essentially of a small resistance element passing through a glass bead on which a thermocouple junction is mounted. The resistance element, or heater, is typically a wire about 5 mm in length and perhaps 25 μ in diameter (see note 3). For voltage measurements it is connected in series with a resistor of low reactance. The thermocouple junction develops a millivolt-range d-c voltage which is a function of the current passing through the heater wire.

In making a-c measurements with a thermal converter, a small d-c supply voltage is adjusted until the galvanometer in the converter circuit indicates a null. Then a variable d-c voltage supply is substituted for the a-c voltage being measured and adjusted until the detector again indicates a null. The d-c heater voltage, which can be measured accurately with a potentiometer, is then equal to the a-c rms voltage.

Transfer instruments of various types are developed at NBS for use in calibrating a-c measuring devices and other transfer instruments. Agreement between the accurately known equivalent a-c and d-c heater inputs is within ± 0.01 percent at audiofrequencies.[4] The low reactances of these devices permit their use over a wide range of frequencies.

Voltage calibrations having an accuracy of ± 0.01 percent are performed at the Bureau by means of transfer instruments incorporated in consoles (see note 3). The equipment is usable for calibrations at potentials up to 750 v and currents to 50 amp. Such calibrations are usually expressed as the a-c–d-c difference of the transfer instrument being calibrated. These determinations are made on each range at one or more frequencies and once determined should be repeated at intervals of about 5 years.



The RF micropotentiometer is used as a transfer device in making accurate measurements of low-level, high-frequency voltages. The thermo-element heater connects the center terminal of the coaxial input connector with the center terminal of the output connector (*right*), which has been modified to include an annular resistor across the output. The thermal element is in a glass bead at its center.

The Bureau is constantly seeking improved calibration accuracy with simplified methods and equipment. The product of one such program is the differential thermocouple voltmeter (DTVM),[5] which consists of two thermal converters mounted side by side. The heater of one is energized by the a-c voltage being calibrated and the other by a calibrated d-c voltage supplied by a zener diode. The two thermocouple junctions are connected in opposition in series with a galvanometer calibrated in percentage difference. This instrument makes possible calibration convenience and speed, with a self-calibration only twice daily.

High-Frequency Measurements

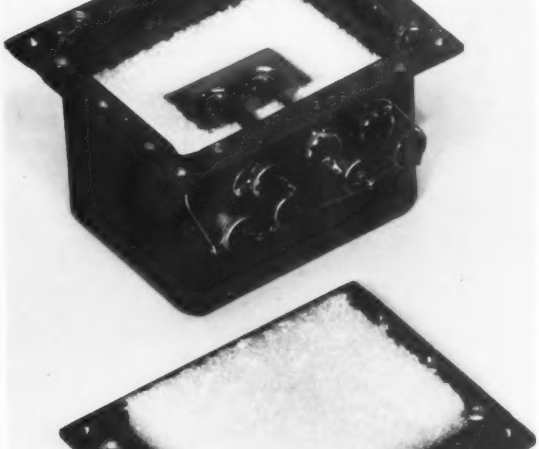
The exploitation of high frequencies with the continuing advance of the technological barrier has led to new test equipment and the need for new standards for these frequencies. Inaccuracies in measuring voltage, due in part to changing circuit constants, become appreciable as the frequency is increased above 1 Mc/s. VTVM errors of ± 0.5 percent at low frequencies increase to ± 2 percent at 10 Mc/s, ± 10 percent at 100 Mc/s, and ± 25 percent at 1000 Mc/s.[6] The VTVM, widely used because of its comparatively small effect on the circuit being probed, contributes substantial errors which vary with time.

Both the characteristics of high radiofrequencies and the shortcomings of measurement equipment reduce the precision of rf voltage standards. The Bureau maintains rf voltage standards for frequencies up to 1 Gc/s and is constantly developing new calibration devices using materials and techniques brought forth in the advance of the art. This has resulted in a family of transfer instruments used for rf voltage calibrations at the Boulder Laboratories.

High-Frequency Calibration

The AT (attenuator-thermoelement) voltmeter and the thermal voltage converter are two of the transfer devices developed by the Bureau to meet the need for accurate and stable high-level rf voltage standards.

The AT voltmeter consists essentially of an rf attenuator which operates in both the capacitive and waveguide-below-cutoff modes.[7] The traveling piston of the attenuator carries a thermoelement, the output of which is indicated on a d-c millivoltmeter or by a potentiometer. It can be used at high voltages (up to



The differential thermocouple voltmeter, developed recently at NBS, is used as a transfer instrument in making accurate a-c calibration measurements without all the steps used with conventional transfer instruments. It contains two thermoelements, one connected to unknown alternating voltage and the other to calibrated direct voltage.

800 c and high frequencies (up to 1000 Mc/s). The great attenuation adjustment range permits the use of the AT voltmeter over a voltage range of 1000 to 1, but the insertion loss varies greatly with frequency. Unlike many other devices, the AT voltmeter is stable within the accuracy of its original calibration (about ±1 percent) for a year or longer.

The d-c output voltage of the thermoelement depends on the input rf voltage and on the position of the attenuator piston, which is set by means of a micrometer. This instrument is calibrated at various fixed frequencies by varying the micrometer in discrete steps and setting the rf input voltage for constant d-c output voltage. Curves can be drawn from this calibration, which makes it possible to use this instrument at any frequency between the fixed frequencies of calibration and any voltage level out to the extreme of the micrometer.

The thermal voltage converter consists of a precision high-frequency resistor in series with a UHF thermoelement encased in a coaxial metal tube fitted with a coaxial input connector.[8] This instrument is usable to 100 Mc/s with very small correction. It is calibrated by the same technique used with the low-frequency thermal converter.

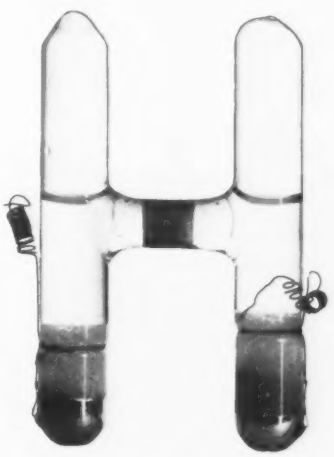
Facilities especially for voltmeter calibration from 30 kc/s to 1 Gc/s have been developed at the Electronic Calibration Center of the NBS Boulder Laboratories.[9] Console positions for voltmeter calibration[10] incorporate built-in thermal voltage converters for specific frequencies and levels. One console group houses thermal voltage converters and associated circuitry for 30, 100, and 300 kc/s while another contains those for 1, 3, 10, 30, and 100 Mc/s. Six thermal voltage converters permanently mounted under the voltage reference plane of each console cover the range from 0.1 to 50 v. Three other thermal voltage converters are used externally with appropriate matching networks for voltages from 50 to 400 v. A third console group houses fixed AT voltmeters permanently mounted under the voltage reference plane of the console and covers the range from 0.2 to 20 v at 300 and 400 Mc/s.

Each console has two operating positions, each offering a selection of two of the console's four frequencies. This arrangement permits several voltmeters to be calibrated simultaneously. Accuracy is maximized by this specialization, by the inherent stability of the devices themselves, and by the use of advanced facility and circuit design features. These features include fully shielded, stabilized, and crystal-controlled rf voltage sources; fully shielded work areas; temperature, dust, and humidity control; and powerline regulation, filtering, and shielding.

Low-Level Calibration

Calibration of voltmeters and signal generators at low rf voltage levels, from 1 μv to 0.1 v rms, at frequencies from 30 kc/s to 900 Mc/s, is done with a specialized thermal converter called an rf micropotentiometer.[11] This device consists of a thermocouple mounted in a glass bead on a heater wire connecting the center conductors of the input and output coaxial connectors. The rf output connector is modified to include a precisely dimensioned annular resistor, designed so that the device has almost no reactive effects and is virtually frequency insensitive to above 300 Mc/s. The rf micropotentiometer acts like a very low-impedance voltage source. The low-impedance output resulting from the use of the shunt resistor makes it possible to produce an accurately known rf output as low as 1 μv. Rf micropotentiometers are calibrated by means of the a-c–d-c difference technique.

Rf micropotentiometers are built into a microvolt calibrator at the Boulder Laboratories for calibrations at levels below 0.1 v rms. This calibrator uses variable frequency rf sources and receivers and is characterized by careful shielding.



A single saturated standard cell.

NOTE: *Additional NBS papers in the field of electrical measurements can be found in Volume I* (Electricity and Electronics) *of* NBS Handbook 77, Precision Measurement and Calibration. *This three-volume handbook can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, $19.75, or Volume I alone can be obtained there for $6.00.*

[1] Test fee schedules of the National Bureau of Standards, *available from the National Bureau of Standards, Washington, D.C., 20234, on request.*

[2] Certification of unsaturated standard cells discontinued, *NBS Tech. News Bull.* **45,** *124 (July 1961).*

[3] Thermal converters as ac-dc transfer standards for current and voltage measurements at audiofrequencies, *by F. L. Hermach, J. Res. NBS* **48,** *No. 2, 121 (Feb. 1952).*

[4] Audiofrequency voltammeter, *NBS Tech. News Bull.* **42,** *170 (Sept. 1958).*

[5] A differential thermocouple voltmeter, *by J. E. Griffin and F. L. Hermach, AIEE Trans. (Communications and Electronics) paper No. 62-819 (1962) and* Differential thermocouple voltmeter, *NBS Tech. News Bull.* **46,** *123 (Sept. 1962).*

[6] Precision calibration of rf vacuum tube voltmeters, *by L. F. Behrent, NBS Tech. Note 121 (Dec. 1961).*

[7] Stable radiofrequency voltmeters, *NBS Tech. News Bull.* **40,** *29 (Feb. 1956).*

[8] Thermal voltage converters for accurate voltage measurements to 30 megacycles per second, *by F. L. Hermach and E. S. Williams, AIEE Trans. (Communications and Electronics)* **79,** *200 (July 1960).*

[9] The facilities and services of the electronic calibration center, *NBS Tech. News Bull.* **42,** *222 (Nov. 1958).*

[10] Rf voltmeter calibration consoles, *NBS Tech. News Bull.* **41,** *147 (Oct. 1957).*

[11] Radiofrequency micropotentiometer, *NBS Tech. News Bull.* **35,** *33 (Mar. 1951);* Accurate radiofrequency microvoltages *by M. C. Selby, Trans. AIEE* **72,** *pt. I (1953); and* Application of rf micropotentiometers for calibration of signal generators to 1000 mc, *by L. F. Behrent, NBS Tech. Note 37 (Jan. 1960).*

MERCURY-TIN SYSTEM INVESTIGATED

DENTAL AMALGAM is used in more than three-fourths of all dental fillings. However, it has certain properties which limit its usefulness, such as a tendency to flow under low compressive loads, and a susceptibility to brittle fracture at moderately high loading rates. A better knowledge of the mercury-silver-tin system, on which dental amalgams are based, is necessary if the alloy is to be improved.

In order to study the ternary system, the constitution diagram for the mercury-tin binary system must first be established. Recently, D. F. Taylor and Claire L. Burns of the dental research laboratory investigated the constitution of the mercury-tin system as an essential first step toward the understanding of dental amalgams.[1] Their results indicate that the system is more complex than previously reported. Additional evidence for the beta phase was obtained; the results show that the gamma phase composition limits should be changed from earlier values; corroborative evidence for the delta phase was found, and evidence for a previously unreported epsilon phase was discovered. On the basis of these results, a revised mercury-tin diagram has been proposed.

The number of published investigations of the mercury-tin system is small, and many of them are confined to studies of portions of the system. Study has been limited partly by experimental difficulties arising from the low melting point of mercury and partly because of the limited commercial application of these materials.

Three experimental methods were chosen for the present investigation: differential thermal analysis, diffusion and chemical analysis, and X-ray diffraction. As thermal analysis was the method originally used in detecting both the beta and delta phases, its employment in this study offered a direct check on these findings. In order to obtain sufficient sensitivity, a differential method of thermal analysis was employed using mercury as a reference substance. After annealing at selected temperatures, the mercury-tin specimens were placed in a heating tube along with a reference specimen of pure mercury, and thermocouples were inserted in both specimens. The whole assembly was heated in a furnace and readings of the specimen temperature and of the differential temperature were made at regular intervals, normally every 2 min. A total of 153 heating and cooling curves was thus obtained on 18 experimental alloys and pure mercury and pure tin calibration samples. The heating and cooling curves show an arrest, i.e., a change in slope, when a phase change occurs.

The method of diffusion and chemical analysis parallels the normal procedure in the use of dental amalgams and offered the possibility of clarifying the mechanisms of the amalgam setting reaction. In this method, a series of experiments was performed in which ingots of tin were exposed to liquid mercury for varying periods, annealed, and then serially sectioned and analyzed.

X-ray diffraction was selected as an adjunctive method to the other two. As a separate method of identification it permitted confirmation of phase sequences proposed by chemical analysis.

The revised mercury-tin diagram (see illustration) is based on the combined results from these three experimental methods. In this diagram the liquidus curve remains essentially unchanged, except that it has been lowered slightly in the alpha + liquid and beta + liquid regions. This lowering is based on thermal analysis results.

The existence of the beta phase at elevated temperatures appears to be well established, although composition limits and eutectoid temperature remain to be confirmed. Thermal analysis results suggest a temperature of 197 °C as approximately correct for the beta eutectoid temperature.

The gamma peritectic temperature[2] of 213.9 °C, also based on thermal analysis, agrees well with previous values. However, the remainder of the gamma region has been considerably altered on the basis of data from thermal analysis studies and X-ray diffraction. The overall picture of the gamma region as a narrow band swinging to higher mercury contents at lower temperatures is somewhat unusual because of the size of the swing relative to the width of the region.

In the modified mercury-tin diagram two additional peritectic phases labeled delta and epsilon are shown. These phases are located on the basis of combined thermal analysis and diffusion results. The delta phase was readily associated with a strong arrest at 91.4 °C observed on thermal analysis and confirms previous work. The epsilon phase composition limits are sim-

ilarly set from the observed composition range for the phase with the highest mercury content in diffusion specimens, and are more certain than those of the delta region. The peritectic temperature of the epsilon phase is not so definitely known, but on the basis of thermal analysis and diffusion specimens is indicated as 58 °C. The peritectic phase at −34.6 °C has not been presently investigated and is merely reproduced here as previously determined (see illustration), designated as zeta.[3]

Three strong thermal arrests at 67.1, 106.1, and 118 °C remain to be explained. On the basis of thermal data alone, these arrests appear to represent peritectic phase formations but no other affirmative evidence for such phases was found. Since a closely spaced series of phases seems unlikely, the arrests are merely indicated by dashed lines in the graph.

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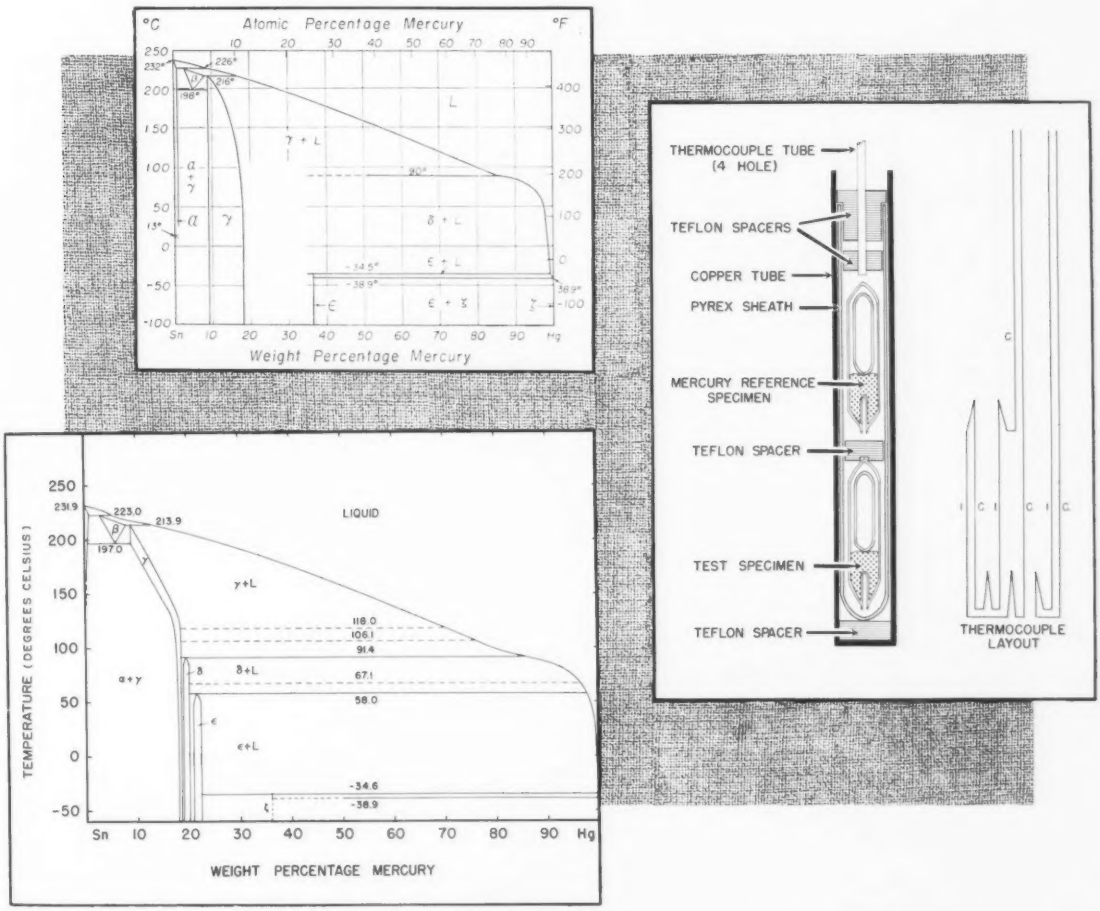
[1] *For further technical details, see* An investigation of the constitution of the mercury-tin system, *by Duane F. Taylor and Claire L. Burns, J. Res. NBS* **67A** *(Phys. & Chem.), 55–70 (1963).*

[2] *The peritectic temperature is that temperature at which the liquid phase is in equilibrium with two solid phases.*

[3] Metals Handbook, *American Society for Metals (Cleveland, Ohio, 1948).*



Above, left: **Currently accepted mercury-tin constitution diagram as given in the Metals Handbook. A recent NBS study showed that the mercury-tin system is more complex than previously reported; as a result, this constitution diagram has been modified.** *Lower left:* **Proposed mercury-tin constitution diagram. The existence of the beta phase at elevated temperatures appears to be well established. The composition limits of the gamma phase have been shifted. Evidence for the delta phase has been found and possible evidence for a previously unreported epsilon phase was discovered. The epsilon peritectic temperature, which is not definitely known, is indicated at 58 °C.** *Right:* **Arrangement of differential thermal analysis specimens used in the study of the mercury-tin system. This tube was inserted into a vertical tube furnace to carry out heating and cooling runs. The drawing on the right shows the thermocouple arrangement. A 28-gage iron-constantan couple was used to measure the temperature of the specimen.**

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National Standard Reference Data System

THE BUREAU has been given responsibility for administering the National Standard Reference Data System recently established by the Office of Science and Technology, Executive Office of the President, on the recommendation of the Federal Council for Science and Technology. The System will provide critically evaluated data in the physical sciences on a national basis, centralizing a large part of the present data-compiling activities of a number of government agencies.

The National Standard Reference Data System represents an attempt to solve an important part of the general problem of communicating scientific information to users. Its aim is to develop a storehouse of standard reference data to assist in the advancement of science, technology, and the national economy. This is to be achieved through a broad-based, comprehensive effort by scientists both in and outside government.

"Standard reference data" are critically evaluated data on the physical and chemical properties of materials, authoritatively documented as to reliability, accuracy, and source. Tabulations of such data are of great value to the scientist or engineer who is designing an experiment or equipment, for the individual worker is thus relieved in part of the necessity of searching the literature and attempting to evaluate data in fields in which he is not expert. Also through study and analysis of standard reference data, areas of science in which additional work is needed become more clearly defined, and relationships not previously apparent are recognized.

Unfortunately it is often difficult or impossible to locate the data that are needed for a specific use. In a recent study by the American Institute of Chemical Engineers,[1] three commonly used sources [2] of standard reference data were analyzed in terms of the availability of data on 16 important properties (such as specific heat, viscosity, thermal conductivity, and vapor pressure) for 13,150 compounds. The average number of compounds for which data were available covering any property was 5 percent, and for only one property were as many as 11 percent of the compounds covered. Undoubtedly many additional data on these compounds exist in the literature, but until they have been evaluated and compiled they are of little value to scientists and engineers.

The National Bureau of Standards, as well as other organizations in this country and abroad, has been active in the compilation of standard reference data for many years. However, in view of the great accumulation of unevaluated data over the past few years, the present accelerated production of new data, and the urgent needs of American science and industry, it has become apparent that a substantially greater effort, planned and coordinated on a national basis, is needed.

The National Standard Reference Data System (NSRDS) will consist of a National Standard Reference

Excerpt from an Announcement by the Office of Science and Technology, Executive Office of the President June 7, 1963

Dr. Jerome B. Wiesner, Director of the Office of Science and Technology in the Executive Office of the President, today announced the establishment of a National Standard Reference Data System. This national effort will be administered by the National Bureau of Standards, which is already compiling standard data. The system integrates to a single point of responsibility the present data-compiling activities of the National Bureau of Standards, Department of Defense, Atomic Energy Commission, National Aeronautics and Space Administration, the National Science Foundation, and several other agencies.

The announcement follows the action taken by the Federal Council for Science and Technology, a government-wide group of top level agency officials in science and technology, based upon recommendations of its Committee on Scientific Information. According to Adm. Charles B. Martell of the Office of the Secretary of Defense, Chairman of the Committee on Scientific Information, the intent is to provide an articulated system of activities under such coordination and direction as to ensure a compilation of data meeting quality standards, and also to maintain continuous policy guidance of the system at the level of the Executive Office. The need to improve scientific and technical information in the Federal government has been increasingly apparent during recent years.

Program Endorsed at NAS–NRC Meeting

On June 20 the National Standard Reference Data System was presented to and endorsed by representatives of science, industry, and government at a meeting of the Advisory Board of the Office of Critical Tables, National Academy of Sciences—National Research Council. Speakers were Dr. Frederick Seitz, President of the National Academy of Sciences; Dr. F. D. Rossini, Chairman, Executive Committee, Office of Critical Tables; Dr. Guy Waddington, Director, Office of Critical Tables; the Hon. J. Herbert Hollomon, Assistant Secretary of Commerce for Science and Technology; Dr. A. V. Astin, Director, NBS; W. M. Carlson, Director of Technical Information, Department of Defense; T. M. Marshall, Jr., Executive Secretary, American Society for Testing and Materials; Dr. D. R. Miller, Division of Research, Atomic Energy Commission; Dr. R. L. Bisplinghoff, Director, Office of Advanced Research and Technology, National Aeronautics and Space Administration; Dr. Paul Chenea, Vice President, Purdue University; Dr. D. H. Clewell, Director of Research and Engineering, Socony Mobil Oil Company; Dr. Dwight Gray, Office of Science Information Service, National Science Foundation; Dr. M. B. Wallenstein, NBS; Dr. U. Fano, NBS; Dr. C. W. Beckett, NBS; and Dr. H. van Olphen, National Research Council Commitee on Colloid and Surface Chemistry.

Data Center at NBS, and various other Standard Reference Data Centers in other government agencies and at universities, research institutes, and other nongovernment organizations. In order for such centers to be a part of the NSRDS, they will be required to meet quality standards established by NBS. However, the independent and operational status of existing critical data projects will be encouraged.

The initial emphasis for establishing new standard data compilation projects will be in subject-matter areas where no effort is now being applied or where the existing effort falls far short of meeting important needs of government, science, or industry.

An Advisory Board will review and recommend policy relative to the operation of the NSRDS. It will include representation from, among others, the National Academy of Sciences, the National Science Foundation, and Federal agencies engaged in research and development.

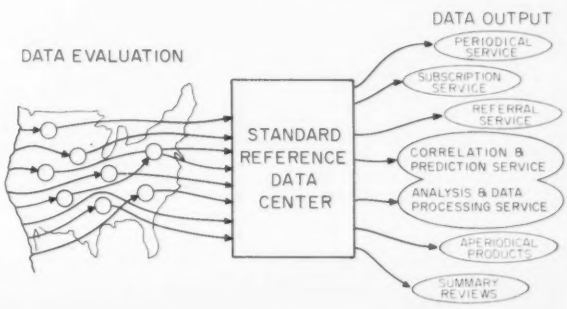
The NSRDS will be conducted as a decentralized operation across the country, with central coordination by the National Bureau of Standards. As presently planned, the program will consist of three parts: an input from scientists in many different locations, a central source of the evaluated data at NBS, and an output system geared to the needs of the nation's scientists and engineers.

Input: The input will come from scientists who are comprehensively reviewing the literature in their fields of specialization and critically evaluating the data for ultimate inclusion in the storehouse of standard reference data. These scientists may be in universities or in industrial or government laboratories; some will be at NBS. They will work singly or in small groups oriented to the traditional scientific disciplines. At the same time other scientists, similarly located, will be engaged in experimentally determining the standard reference data that do not exist in the literature. Clearly, the interplay between the two groups must be close and continuous.

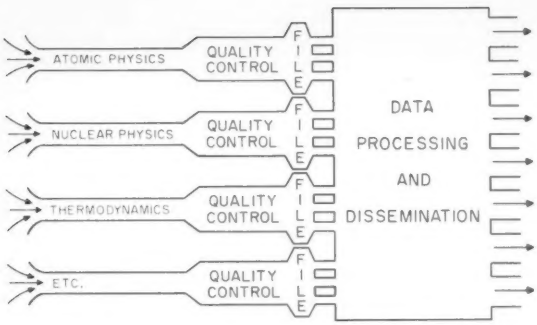
Central Core: The central core will consist of the Standard Reference Data Center at NBS, where the evaluated data will be located in punched cards, on magnetic tape, in notebooks, and in many other forms, all mechanized for storage and retrieval. A review and control office will label the incoming data as to relative quality and reliability. The SRD Center will classify the data into as many major and minor categories as are required by the needs of the data users.

Output: The output will take the form of a series of services aimed at different technical levels and tailored to the needs of various segments of industry. In general, it will be oriented toward the application of the data, rather than toward a field of science. According to present plans, the output services will be provided by the SRD Center and will eventually include:

(1) Periodical Service
designed to keep the user up to date on new data acquisitions in the SRD Center. It will provide information on the data available in the Center (but will not provide the actual data) by means of a monthly news letter and by annual and semiannual reviews of data acquisitions.



Plans for the National Standard Reference Data system call for a decentralized operation administered and coordinated by NBS. Scientists in data evaluation groups throughout the country will scan physical science literature in their fields of specialization and will produce evaluated data compilations and reviews as input to the System. This input will be sent to the Standard Reference Data Center at NBS, where the evaluated data will be stored for mechanized retrieval. The various data output services will be directed toward the specialized needs of different industrial segments and technical levels.



Proposed plan of operation for the Standard Reference Data Center at NBS. The incoming evaluated data will be separated by subject matter field (e.g., atomic physics, thermodynamics, etc.) for handling by different groups within the Center. After the data have been labeled for quality and reliability, they will be classified and filed to permit rapid retrieval in the form required by different user groups.

(2) SUBSCRIPTION SERVICE
in which the user pays to receive all available data on a specific subject on a continuing basis. These data packages will be designed to meet the needs of specific industries, industry groups, or Government research and development programs.

(3) REFFERAL SERVICE
which will handle narrow, one-time requests for data by referral to the files of the SRD Center. In general, this service will take care of needs that are not met by the other output services.

(4) CORRELATION AND PREDICTION SERVICE
for computing values wherever possible in areas where some data exist, but where requests come in for specific information not contained in the SRD Center. Values will be computed by making use of correlations based on molecular structure and the properties of related compounds.

(5) MATHEMATICAL AND STATISTICAL SERVICE
which will offer mathematical and computer techniques to customers for evaluating new data for subsequent inclusion in the files of the SRD Center or for individual use. This service will also provide techniques to assist in the Correlation and Prediction Service.

(6) APERIODICAL PRODUCTS
including tabulations, review monographs, review papers, computer card decks, and computer tapes, will constitute the formal end products of the SRD Center.

(7) SUMMARY REVIEWS
to provide a rapid assessment of the state-of-the-art in fields where there are few data but which must suddenly be explored because of scientific breakthroughs or crash programs.

In planning the details of the program, the needs of American industry, academic scientists, and Government laboratories must all be ascertained and taken into account. Undoubtedly limitations in funds and manpower will require establishment of a priority system of some kind. In choosing work to be undertaken from such a vast field, the Bureau will be assisted by the Advisory Board, interagency panels, expert consultants in the subject-matter areas, and working committees of the scientific and engineering societies and industry associations that are active in the field of critical data.

It is expected that ultimately a majority of the senior scientists at the Bureau will participate in the work. In addition, distinguished scientists will be invited to spend some months at the Bureau, using its technical, administrative, and information retrieval services for the purpose of producing critical reviews and compilations.

[1] Road map to physical property correlations, *by R. A. Peterson, W. M. Carlson, N. E. Dahl, and R. H. McBride, Am. Inst. Chem. Eng. National Meeting, Cleveland, Ohio, May 7, 1961.*

[2] Chemical Engineering Handbook, *edited by J. Perry (McGraw-Hill Co. Inc., New York, N.Y., 1950)*; Handbook of Chemistry and Physics, *41st ed. (Chemical Rubber Publ. Co., 1959–60)*; *and* International Critical Tables (*McGraw-Hill Publ. Co., Inc., New York, N.Y., 1927–29*).

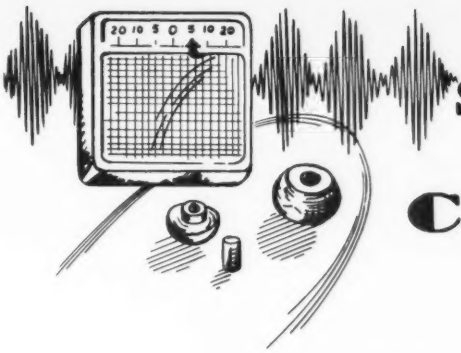
NBS Chemist is Co-Author of Book

Harry C. Allen, Jr., Chief of the NBS Analytical and Inorganic Chemistry Division, and Paul C. Cross, President of the Mellon Institute in Pittsburgh, Penn., are co-authors of a book entitled *Molecular Vib-Rotors, The Theory and Interpretation of High Resolution Infrared Spectra* (John Wiley & Sons, New York, $13.50). Dr. Cross is also a member of the NAS–NRC Technical Advisory Committee to the NBS Physical Chemistry Division.

This book presents the theory of vibrating-rotating molecules and gives and applies this theory to the analysis of spectral bands. Although the basic theory for interpreting such spectra has been developed extensively since the end of World War II, this book relates the diverse notations and summarizes much of the experience which has accumulated in applying the theory to the analysis of observed spectra.

More than half the book is devoted to developing the basic theory of vibrating-rotating molecules thoroughly enough for the reader to understand the mathematical derivations and to extend and adapt these methods to new problems. Theories for both the rigid rotor and semirigid rotor approximations are developed at length, and solutions for these approximations are discussed in some detail. Centrifugal distortion, Coriolis interaction, selection rules, and line strengths are also discussed.

The last part of the book features illustrative applications of the theory to linear, symmetric, and asymmetric rotors. Solutions to these problems are somewhat more specialized than those in the earlier part of the book. Selection rules as well as equations for the line strengths are given for each case.



STANDARDS AND CALIBRATION

Recent Publications

NBS Technical Note* 188 (20¢), by E. S. Williams, is concerned with the *Calibration of Volt-Ampere Converters.* These converters need normally be calibrated by NBS for determination of a-c–d-c differences every five years. However, the d-c calibration, which can be performed in the user's own laboratory, should be made at 6- to 12-month intervals. This Technical Note suggests procedures by which such d-c calibrations can be made, and describes an easily constructed voltage comparator which simplifies the test procedure and calculation of results. Circuits, precautions, and procedures are described, equations are developed, and calculations are illustrated for determining the volt-ampere converter corrections.

Practical Methods for Calibration of Potentiometers are described by David Ramaley in Technical Note 172 (30¢). This Technical Note presents the more feasible means of calibrating potentiometers, describing them in considerable detail. Potentiometer circuitry, particularly as related to calibration, is discussed, with primary consideration given to the required circuit measurements. Emphasis is placed on the use of the universal ratio set as the basic implement for accomplishing the major portion of potentiometer calibrations. Instructional material is presented in the form of examples, chosen to represent principles applicable to a variety of instruments.

Extension of Waveguide Power Calibration Service

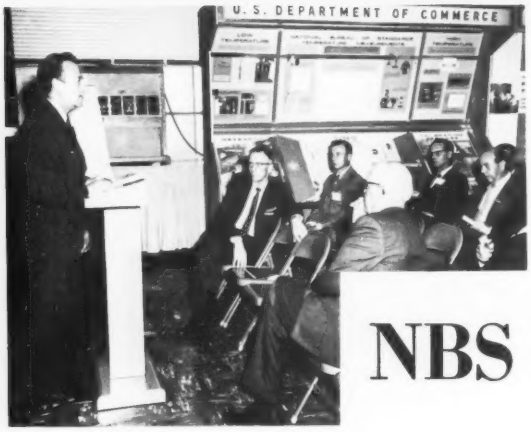
A limited power calibration service in WR62 waveguide (12.4 to 18 Gc/s) was announced in the February 1963 issue of the *Technical News Bulletin.* This service now is extended to include the measurement of the calibration factor of bolometer units and bolometer-coupler units. The calibration factor for bolometer units, K_b, is defined as the ratio of the substituted d-c power in the bolometer unit to the microwave power incident upon the bolometer unit. The calibration factor for bolometer-coupler units, K_c, is defined as the ratio of the substituted d-c power in the bolometer unit on the side arm of the directional coupler to the microwave power incident upon a nonreflecting load connected to the main arm. Calibrations are performed using a self-balancing bolometer bridge which maintains the bolometer unit at a constant resistance.

Bolometer units to be calibrated should be of the fixed-tuned or untuned broadband type, and must be fitted with a waveguide flange compatible with the UG–419/U cover flange. A bolometer element of the barreter type should have a nominal resistance of either 100 or 200 ohms at a bias current between 3.5 and 10 ma; an element of the thermistor type should have a nominal resistance of either 100 or 200 ohms at a bias current between 5 and 15 ma.

Bolometer-coupler units to be calibrated should consist of a three-port coupler with a bolometer unit of the fixed-tuned or untuned broadband type permanently attached to the side arm of the coupler. The coupler must be fitted with waveguide flanges compatible with the UG–419/U cover flange. The directional coupler should have good design features with a directivity of 40 db or greater, a coupling ratio in the range 3 to 20 db, and with a main-guide VSWR no greater than 1.05.

In reporting calibration results, the calibration factor of a bolometer unit normally can be given to an accuracy of within ± 1.5 percent. The calibration factor of a bolometer-coupler unit can be given to an accuracy of within ± 1 percent. Calibrations usually will be made at a nominal power level of 10 mw. Suggested calibration frequencies are 13.5, 15.0, and 17.0 Gc/s, although calibrations at frequencies throughout the range of 12.4 to 18.0 Gc/s are available.

**Technical Notes may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.*



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NBS Washington Laborato

On May 11, 1963, the Bureau's Washington laboratories were thrown open to the public for the first time in many years.[1] The open house program was a part of the celebration of the 60th anniversary of the founding of the Department of Commerce.

Approximately 7,000 persons visited the Washington laboratories during the day and went on selected tours among the more than 100 laboratories and special exhibits that were open for public inspection. Among the items on display were an electric arc that produces temperatures up to 75,000 °K, an ultrasonic thermometer that measures temperatures within a few degrees of absolute zero, a helium-neon laser that shows promise for precise measurement of long distances, and a 50,000-curie cobalt 60 radiation source—the largest single radiation source ever shipped from Oak Ridge National Laboratory. Two NBS-produced motion pictures, "Scatter Radar" and "Assignment—Weights and Measures," were also shown to the guests.

At the NBS Boulder Laboratories, Boulder, Colo., the Department of Commerce 60th anniversary was commemorated by several programs, including special tours and open houses for high-school students and the general public, as well as by an anniversary display at the Colorado-Wyoming Bi-State Science Fair held at the Laboratories April 19–20. Among the items on display were the cesium-beam atomic frequency standard ("atomic clock"), which measures time intervals with a precision of one part in 100 billion, and the electronic computation facility, where vast quantities of scientific data obtained by the varied research projects of the Boulder Laboratories are processed and analyzed by electronic computers.

As the Nation's measurement standards laboratory, the Bureau carries on a diversified research program, including most major areas of the physical sciences. To provide *Technical News Bulletin* readers with a representative cross section of this broad program, brief descriptions of the May 11th laboratory presentations are given below under the organizational division headings.

[1] The "open houses" held in 1955, 1956, and 1957 were invitational affairs.

Top of page: **Secretary of Commerce Luther Hodges** (*right center*), **Assistant Secretary for Science and Technology J. Herbert Hollomon** (*left*), **and NBS Director A. V. Astin** (*center*) **preside over a preview of the NBS Open House for Government officials, Congressional staff, and members of the press.**

Electricity

Absolute current balance. The NBS absolute current balance is used to make high-precision absolute current measurements, to evaluate the absolute ampere, and to check the Bureau's saturated standard cells.

Resistance and Reactance Measurements. The practical system of measurements upon which the electrical science and industry of our nation are based starts with national reference standards of resistance and electromotive force. From these basic building blocks all other electrical quantities are derived by means of highly accurate ratio devices, techniques, and transfer principles. The units of resistance and voltage embodied in the basic standards are established by means of so-called "absolute" measurements which, in turn, involve the mechanical units of length, mass, and time.

Standard cell laboratory. The reliability of all types of electrical and electronic equipment depends upon the accuracy with which their components can be measured and controlled. Such measurement is based on the national standards of resistance and electromotive force maintained by the Bureau. The NBS standard cell laboratory maintains the national standard of electromotive force, consisting of 44 cells of a special type, and conducts research to improve the precision and stability of these cells under varying conditions of temperature and pressure.

Zener diodes laboratory. Establishment and maintenance of electromotive force standards is a basic NBS function. When the extreme stability of a saturated cell is unnecessary, an unsaturated cell may serve as the standard of emf. Since in some cases unsaturated cells are being replaced by zener diodes, the characteristics of these components as reference standards must be determined. Stability, temperature coefficient, and suitable circuitry are under study. A zener diode hav-

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ing the stability of an unsaturated cell would provide a rugged, easily transported reference standard.

Watt-hour meters. Measurement of the $30 billion yearly sale of electrical energy and equipment is based on the fundamental electrical standards established and maintained by NBS. These standards are used to calibrate master standards for universities, private laboratories, manufacturers, utilities, and regulatory agencies. From the Bureau's standard watt-hour meter the master standards of the public utility commissions and the power companies are calibrated.

High-voltage measurements—transformer ratios. The Bureau must provide the calibration services necessary to promote uniformity and accuracy in high-voltage measurements throughout the United States. NBS research in high-voltage measurements also seeks to extend the unit of voltage above the level conveniently reached with the potentiometer and volt box and to develop techniques for its dissemination. The Bureau cooperates with other national standardizing laboratories in achieving international uniformity in electrical measurements. The "Mighty Pike," so-called because of its 1-picofarad capacity, is an NBS device for measuring transformer ratios with an accuracy of 2 to 3 parts in 100,000. It has been used in cooperation with the Canadian government to test a 350,000-v transformer built for the Ontario Hydroelectric Power Commission.

Dielectrics laboratory. The properties of electrical insulating materials are vitally important, as they often set the limits of voltage, frequency, or temperature at which various devices can be operated. Users of these materials and those interested in understanding basic dielectric phenomena must have accurate values of the electrical properties of such important insulating materials as polymers. At the Bureau, an intensive study program is in progress to obtain these values.

Metrology

Color measurements. The color specifications used today by American science and industry are based on color measurements carried out in the Bureau's colorimetry laboratory. These measurements are based on three principal factors—the distribution of light source, the spectrum of the color sample, and the sensitivity of the human eye.

Photogrammetry. The accuracy of maps obtained by aerial photography depends to a great extent on the optical characteristics of aerial camera lenses. These characteristics—focal length, distortion, and resolving power—control such qualities as scale size, true image position, and picture clarity. In order to assure the maximum utility of these lenses by the Armed Forces and other federal and state agencies, as well as by industries that develop public utilities, the Bureau conducts a calibration program to measure lens characteristics.

Photographic research. Photographic research is carried on at the Bureau to develop improved methods of measuring the properties of photographic materials, to develop improved physical standards for such measurements, and to cooperate with national and international standardizing organizations in the development of photographic standards. Increasing emphasis has been placed on this program because of the growing use of photography by scientists and technologists in areas such as information storage and retrieval, machine memory systems, photographic production of microminiature components, space vehicle tracking, high-altitude reconnaissance, and high-speed data recording. In a recent study, a high-resolution camera capable of projecting a parallel line pattern of 50,000 lines per inch was developed as a tool for measuring the resolving power of photographic materials.

Measuring length with light waves. A few years ago, the wavelength of the orange-red spectral line of krypton 86 was adopted in place of a platinum-iridium meter bar as the international standard of length. In order that this standard may be readily used for length measurements, the Bureau has developed two techniques. In one, electrical signals are obtained from a photoelectric microscope that automatically scans a distance equal

Above: **One of the most popular stops at the NBS Open House was the operating gold-plating process in the electrolysis and metal deposition laboratory.**

to the spacing between two graduation lines on a length scale. In the second, an optical interferometer automatically determines the distance scanned in terms of wavelengths of light. The resulting data are then fed into an electronic computer which indicates the number of wavelengths measured as customary units of length, such as centimeters or inches.

Length measurements with a laser. In recent experiments, interference fringes were obtained with a modified Michelson interferometer over an optical path of approximately 200 m. This result, achieved by use of a helium-neon laser (*L*ight *A*mplification by *S*timulated *E*mission of *R*adiation) as the light source for the experiments, becomes significant when it is realized that interference fringes obtained by conventional light sources may be observed, at best, over paths of less than 2 m. When effects such as mechanical vibrations and atmospheric variations are overcome in the use of this equipment, it is expected that the accuracy of long-distance measurements may be increased a hundredfold.

Mass measurements. The Bureau is the custodian of the national standard of mass—a platinum-iridium cylinder 39 mm in diameter and 39 mm high—which provides the basis for uniform weight in science, commerce, and industry. The pound and other everyday units of mass are defined by the ratios of their mass to the mass of this kilogram. To assure the precision of the weight-measurement devices used by state and municipal regulatory agencies, the Bureau calibrates the reference mass standards used by these agencies against the national mass standard.

Heat

Automatic thermocouple comparator. Temperatures are often measured by means of thermocouples—devices consisting of two dissimilar metal wires forming a junction at one end and connected to a voltage-measuring instrument at the other. Thermocouples are often calibrated by comparison with a thermocouple of known characteristics. An automatic comparator, which records digital test data on punched tape for as many as 11 test thermocouples, has been developed.

Low-temperature calorimetry. A calorimeter with which a single operator can make accurate measurements over the range 10 to 400 °K (−441 to +261 °F) was demonstrated. Calorimetry, or the measurement of heat, is essential in the establishment of heat standards and in the determination of thermodynamic properties of materials such as rocket fuels and their combustion products.

Ultrasonic thermometer. The growing interest in cryogenics and space environments has increased the need for accurate measurement of very low temperatures. The Bureau is developing an ultrasonic thermometer to determine absolute temperatures in the 1.5 to 20 °K (−457 to −423 °F) range. This instrument will be used to calibrate a group of germanium resistors, which will then be used as working standards in the 1.5 to 20 °K range.

Very high temperature measurements. The study of plasmas has been stimulated by the efforts to control fusion reactions, the need to understand the upper atmosphere (which is essentially a plasma), and investigations of stellar processes. One aspect of the Bureau's plasma research program is a study of the approach to equilibrium, encompassing studies of diffusion and electrical conductivity in the plasma state. A magnetically confined argon plasma, operating at temperatures of 50,000 to 75,000 °K (90,000 to 135,000 °F), is being used in these studies. Temperatures of the plasma are determined by the voltage-current characteristics of small wire probes, by studying the oscillations of the plasma, and by computer analysis of spectral intensity measurements.

Fast-opening photographic shutter. A photographic shutter capable of opening to an area of 1×3 in. in 45×10^{-6} sec has been developed in conjunction with the photography of electrical phenomena of short duration. The action of the shutter depends upon the passage of a heavy current through a strip of aluminum foil. The current causes the foil to compress towards its midline; if two foils are used, mutual repulsion increases the speed of opening.

Radiation Physics

Gamma-ray measurements. The increasing number of industrial and medical applications of radiation has increased the need for (a) information on the effects of radiation on materials and (b) accurate means of measuring radiation. Among the tools used in the NBS research are a 50,000-curie cobalt 60 source, immersed in a "swimming pool," which is used in studies of the effects of high-intensity radiation on polymers; various types of instruments used to detect and measure radiation; and cobalt 60 and cesium 137 sources used in calibrating instruments.

X-ray research and standards. The accurate measurement of X-ray exposure, based on standard techniques developed at NBS, is vitally important to the industrial radiation processor, industrial radiographer, medical therapist, and research scientist. For example, the 4 million radiation therapeutic treatments performed yearly in this country are administered by X-ray machines whose calibrations are referred back to the national standards.

Radioactivity standards. The Bureau has for some years developed and issued standards of radioactivity. These standards are used by industrial, medical, and research laboratories for the calibration of radiation-measuring instruments.

Van de Graaff accelerator. Effective use of high-energy accelerators, nuclear reactors, and controlled thermonuclear power requires an understanding of the properties of the neutron and the way it interacts with matter. The Bureau is contributing to the advancement of knowledge in this field through the development and maintenance of stanlards of neutron source strength and thermal neutron flux, studies of neutron penetration and shielding, measurement of dose produced in matter by neutron radiation, investigations of improved neutron detectors, and measurement of neutron interaction probabilities with nuclei.

Visitors inspect the architect's model of the new NBS laboratories now being built in Gaithersburg, Md.

180-Mev synchrotron. The Bureau's 180-Mev synchrotron, an electron accelerator, is used in the production of high-energy electrons and X-rays. These radiations are used in studies of nuclear structure and in the development of radiation standards and measurement techniques.

Analytical and Inorganic Chemistry

Physical methods of determining purity. The kind and amount of impurities present influence the properties of materials. A new method of determining the purity of a substance is to measure its dielectric constant as it changes from a solid to a liquid. Precise determinations of the fraction of material frozen are plotted as a function of temperature, and from these data the purity of the substance is calculated.

Spectrochemical analysis. Spectrochemical analytical methods save a great deal of time in micro-, nondestructive, and trace-element determinations. In such analyses, the atoms of the materials under investigation are excited to a high-energy state, causing them to emit spectra that are characteristic of their representative elements. From these spectra the elements present in the sample can be determined. Two newly developed excitation sources, a plasma jet for the analysis of solutions and a gas-stabilized arc for the analysis of solids, provide improved sensitivity, accuracy, and convenience in fundamental and applied spectroscopy.

Properties of electrolytes in nonaqueous solutions. A major responsibility of the Bureau is to determine the properties of materials. The properties of aqueous solutions are fairly well defined and data are available. However, little work has been done to determine the properties of acids, bases, and salts in nonaqueous solutions. The display showed some procedures used for determining conductivity, electromotive force, and spectral properties of materials dissolved in nonaqueous solvents.

Standard reference materials. The primary purpose of standard reference materials is to help provide a central basis for uniformity and accuracy of measurement throughout government and industry. The Bureau distributes more than 400 different standard reference materials, including metals, ores, ceramics, and chemicals. These materials are certified to have particular values of such properties as acidity (pH), viscosity, freezing point, density, index of refraction, heat of combustion, chemical composition, and radioactivity.

Instrumental methods of chemical analysis. Physical measurements are playing an increasingly important role in chemistry for purposes of both identification and quantitative determination. Several of the physical techniques for chemical analysis, such as (a) gas chromatography, (b) infrared, visible, and ultraviolet spectrophotometry, and (c) mass and fluorescence spectrometry, were demonstrated.

Growing crystals from solution. Studies of crystallization phenomena are being conducted with large single crystals grown from solution. Both crystals of high purity and crystals purposely contaminated by introducing foreign materials into the crystal-growing solution are studied to determine the mechanism of crystal growth and impurity retention.

Mechanics

Pressure and absorption of sound measured. Three types of sound measurement are made in the NBS reverberation chamber: the amount of sound energy produced by noise sources such as high-speed air jets, fans, blowers, and transformers; the sound-absorbing power of acoustical materials used for quieting offices or large auditoriums; and the sensitivity of microphones in a diffuse sound field.

High- and low-pressure measurements. Extremely high pressures are now being used in industrial laboratories to synthesize materials such as diamonds. Very low pressures are utilized in work on atomic accelerators, in the preparation of pure materials, and in tests simulating the space environment. The Bureau is conducting an active program to meet the needs for a well-defined scale for such pressures and to develop standard measurement techniques in this area.

Fluid mechanics experiments. Demonstrations were given of the generation of water waves by wind action, the development of wind-produced tides, and the resulting effects on harbors or enclosed bodies of water. The characteristics of waves approaching a shoreline and the effect of the slope of a beach on their shape were also demonstrated.

Measuring large forces. The Bureau provides standards and calibration services for the precise measurement of large forces—important in the design of bridges, buildings, and aircraft, in the automatic control

The fire-research laboratory demonstrated the development of fire storms, using small cups of fuel.

of machinery, and in determination of the thrust developed by jet engines and rocket motors. The best method known for calibrating force-measuring devices is with dead-weight machines. When loads exceeding the capacity of present dead-weight machines are required, indirect means utilizing proving rings and dynamometers (load cells) are used.

Viscosity of liquids. Accurate measurement of the viscosity of ordinary liquids is generally carried out by making determinations of the relation between a driving force applied to a liquid and the rate of flow of the liquid. Instruments for performing such measurements are calibrated by liquid standards of known viscosity. A number of liquids of considerable commercial importance and scientific interest cannot be described adequately by a single viscosity. Such materials commonly exhibit a nonlinear relation between stress and rate of strain, and also show pronounced normal stress effects.

Combustion controls laboratory. Flame speed, or burning velocity, is the velocity with which a flame travels through a combustible mixture. The apparatus used at the Bureau to determine flame speeds features a temperature-controlled nozzle burner with which accurate values can be obtained. In current work, a determination is being made of the effects of halogenated hydrocarbons on the flame speed of methane-air mixtures. These halogenated hydrocarbons are flame retardants and small amounts of them reduce flame speed greatly.

Polymers

Ultracentrifuges to measure large molecules. The ultracentrifuge is a powerful tool for accurate measurements of the size and structure of very large molecules. Two different types of these instruments were on exhibit. One has a magnetically supported rotor—that is, a rotor having essentially frictionless bearings—which can be operated over a large range of rotational speeds. The other, supported by a thin wire, is capable of developing extremely large centrifugal forces.

Gamma-ray irradiation of polymers. In the gamma-ray laboratory, radiation is produced by the radioactive decay of cobalt 60. This substance is held in the bottom of a large tank of water 12 ft deep to protect personnel from the radiation. Here the effects of gamma-rays on various types of polymers such as rubber and plastics are studied.

Properties of textiles under impact. Textile yarns made from synthetic materials possess an extraordinary ability to absorb high-speed impact shocks. This characteristic is especially important in airplane-arresting gear, in the parachutes used for the retrieval of satellites, and in the body armor worn by combat soldiers. A technique for measuring this property has been devised. In this technique, a yarn marked at intervals along its length is shot at by a rifle bullet. The subsequent effects on the yarn are recorded photographically at time intervals of as little as ten millionths of a second. The film record is then measured to obtain data on the strain distribution along the yarn and the velocities at which the strains propagate.

Kinetics of polymer oxidation. The relative resistance of various plastics and other polymeric materials to degradation is being studied by analytical procedures. Finely divided portions of these materials are sealed in glass ampoules with air and heated at carefully controlled temperatures. Samples of the atmosphere over the materials are removed at intervals and analyzed for oxygen content. The rate at which oxygen is consumed by the materials—a measure of degradation—is determined at several temperatures and these rates are compared with those of other materials.

Polymer evaluation and testing. The Bureau evaluates commodities made from polymeric materials for other Government agencies. These materials include leather, paper, plastics, rubber, and textiles. Tests are made to determine hardness, strength, abrasion resistance, tear resistance, dimensional stability, and impact resistance.

Standard sample for paper tear test. A standard sample has been developed for a paper-tearing strength test. Such tests are made on papers that will be torn in service—for example, shipping sacks, grocers' bags, and maps. Manufacturers use the sample to control the quality of their products, and in research to develop stronger papers. The standard sample has a uniform, known tearing strength, so that laboratories can use it to check the accuracy of their test procedures.

Dental research. Research during the past 40 years at the Bureau on the physical and chemical properties of dental materials has led to the development of standards of quality used in the United States and other countries. Most of the materials used by dentists are manufactured to meet these high standards.

Metallurgy

Metal fatigue. Government agencies frequently request the Bureau to examine metal parts, such as propellers or aircraft landing gear, that have failed in service. Since fatigue is frequently the cause of such

mechanical failures, investigations are conducted to obtain information on the cyclic stresses that probably caused small fatigue cracks to form, ultimately leading to metal failure.

Nuclear magnetic resonance in metals. The discovery of the nuclear magnetic resonance in metals in 1950 led to an effective tool for studying aspects of the electronic structure of metals and alloys. At the Bureau, the resonance technique is used to measure the magnetic and electric fields inside metals. Information is obtained on the electronic densities in metals as well as on the effects of impurities and other imperfections in metal structure. Alloys of lead with indium, tin, thallium, mercury, bismuth, and antimony are presently being studied.

Stress corrosion of metals. The stress-corrosion cracking or failure of metals may occur under very mildly corrosive conditions in materials subjected to supposedly safe loads. For example, such failures may occur in hooks holding facing blocks to the side of a building, causing the blocks to drop to the ground; or they may occur in the safety bolts of window-washing equipment, jeopardizing the life of the worker. Stress-corrosion failures in heat exchangers are a continuing source of concern in chemical plants along the eastern and gulf coasts of this country. Hence, the stress-corrosion resistance of many metals is extensively studied at the Bureau.

Electron microscopy and imperfections in metals. Imperfections, called dislocations, that occur in metals and affect their strength and other mechanical properties are being investigated at the Bureau. An electron microscope was demonstrated, as well as a high-vacuum evaporator used to make specimens which are then studied in the microscope.

Electrolysis and metal deposition. More information is needed on the fundamental nature of electroplating and the properties of materials employed in the process. Such information would not only contribute to the understanding of electrochemistry, but would also provide a basis for improved processes in the large electrochemical industry.

Inorganic Solids

Mechanical properties of brittle materials. The increased demands in recent years for materials which will perform satisfactorily under extremes of temperature, stress, and environment have placed great emphasis on the utilization of inorganic nonmetallic materials (ceramics). These materials are inherently brittle and, consequently, there is a marked dependence of their mechanical properties on their microstructure. Of the various mechanical properties of ceramics, strength is of major interest because only one tenth to one fiftieth of the theoretical strength is being achieved in structural shapes. As a part of a study of the influence of microstructure on the mechanical properties of ceramics, the Bureau has developed equipment and techniques for simultaneous high-temperature measurement of strength and of the stress-strain relationships in brittle materials as they are stressed to failure.

Viscosity standard samples of glass. Viscosity of molten glass is an important physical property which must be accurately known for designing processes for melting and fabricating of glass. Many glass manufacturers make occasional or periodic measurements of this property for the purpose of controlling the processing operations. This creates a need for a standard sample of glass of known viscosity for calibrating commercial glass viscometers. Standard Sample No. 710, which was recently issued, has been accurately measured for viscosity over the range 520 to 1450 °C. Standard Sample 710 is a soda-lime-silica glass, a composition which closely approximates a composition widely used for container and plate glass. The Bureau is now working on a standard sample of lead-silica glass, which differs markedly from the soda-lime-silica glass in its viscosity-temperature relationship.

High-temperature properties of materials. Today's scientists and engineers need to know how various materials will stand up under the tremendous heats generated in jet planes, rockets, missiles, satellites, and nuclear reactors. The immediate task is not to develop new heat-resistant materials by trial and error; rather, it is to develop means for measuring precisely the physical and chemical properties of already existing materials at very high temperatures. To obtain such basic data more easily and accurately, the Bureau is developing new ways to carry out experiments at high temperatures. A current study deals with methods for determining vapor pressures and related properties of materials such as platinum and refractory oxides at temperatures above 1800 °F. Arc-image and other types of furnaces are used to obtain high temperatures. Microbalances and mass spectrometers are used to obtain the vaporization data.

High-temperature crystal growth. The hardness, resistance to high temperatures, and transparency of certain oxide crystals make them uniquely valuable for many critical uses. Accurate values of the physical properties of these materials are best obtained from large single crystals. The ordinary Verneuil flame-fusion process and a modified process using a plasma flame as the heat source are used to produce such crystals as sapphires (Al_2O_3), rutile (TiO_3), and a variety of other oxides. The processes themselves are being studied to learn the factors affecting crystal perfection.

Elasticity and damping of crystals. The vibrational spectrum of a crystal is a fundamental property upon which many technically important properties such as thermal expansion, thermal conductivity, and specific heat depend. The vibrational spectrum itself depends in part upon the elastic constants, and these are therefore being determined for the refractory oxides as suitable single crystals become available. Several types of point defects in refractory oxides, particularly MgO, TiO_2, and ThO_2, are being studied.

Metal-oxide melting-point standards. Materials which can serve reliably as melting-point standards are essentially limited at the present time to those specified by the International Practical Temperature Scale of 1948. These materials, primarily metals, often must

be utilized only under limited or specialized conditions. To meet the demand for standards more suitable for diversified applications, the Bureau has undertaken a program of precise and accurate determination of the melting points of the metal oxides. Special emphasis has been placed on oxides having melting points ranging between 2000 and 3000 °C.

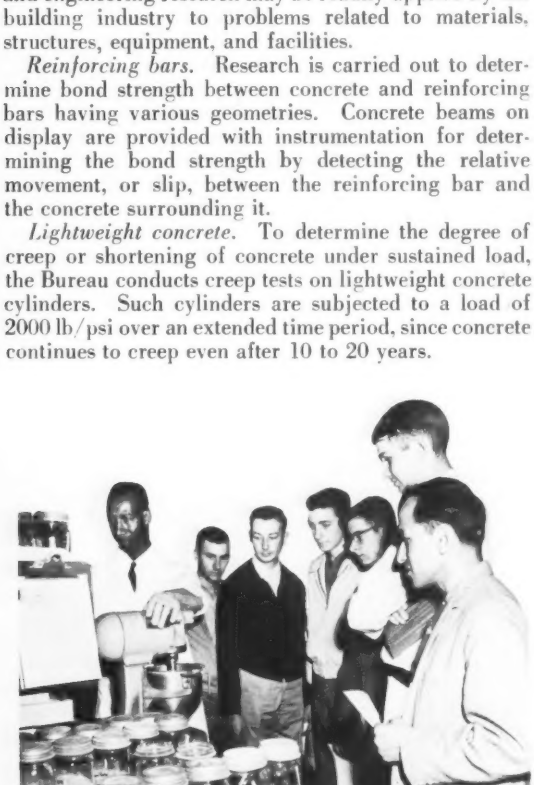
Structure of matter. Many physical and chemical properties of materials are directly dependent upon their atomic configuration. X-ray diffraction analysis can determine the exact position of the atoms within a crystalline solid. NBS conducts research in the application of new methods to structure analysis, determination of structure in wide temperature ranges (−180 to +1000 °C), determination of structures of particular chemical or physical importance, and study of the structure of the vitreous state.

Building Research

Materials research. A primary objective of the Bureau's program is the development of measurement and test methods so that new knowledge in physical sciences and engineering research may be readily applied by the building industry to problems related to materials, structures, equipment, and facilities.

Reinforcing bars. Research is carried out to determine bond strength between concrete and reinforcing bars having various geometries. Concrete beams on display are provided with instrumentation for determining the bond strength by detecting the relative movement, or slip, between the reinforcing bar and the concrete surrounding it.

Lightweight concrete. To determine the degree of creep or shortening of concrete under sustained load, the Bureau conducts creep tests on lightweight concrete cylinders. Such cylinders are subjected to a load of 2000 lb/psi over an extended time period, since concrete continues to creep even after 10 to 20 years.



In the NBS cement-testing laboratory, guests learned about the tests the Bureau makes on the cement used by the Federal Government in all its major construction projects.

Model of a mass fire. During the past war, some air attacks on enemy target cities resulted in mass fires, or fire storms. The Bureau is currently supporting, through contracts, studies of some factors influencing the start of such fires. Fuel in an array of small containers was burned to illustrate some aspects of fires of this type.

Heat, air, and moisture transfer in buildings. The mechanical systems used to heat and cool homes, offices, and other buildings are continually being improved to provide more comfortable living conditions. The efficiency of such systems can be increased through studies of heat, air, and moisture transfer in buildings.

Methods of evaluating paints. Some important properties of paint and related organic coatings are abrasion resistance, ease of cleaning, and resistance to such changes as yellowing and loss of gloss. Apparatus used to determine these characteristics was exhibited. In addition, such devices as adhesion testers, viscometers, mandrels for determining flexibility, impact testers, hardness rockers, and other equipment for measuring physical properties were on display.

Physical tests on portland cement. The quality of portland cement is controlled by physical and chemical laboratory tests. Such tests are carried out by NBS on the cement used by the Federal Government on all major construction projects, including large concrete dams such as Hoover and Grand Coulee, large navigational structures ranging from the Panama Canal to the St. Lawrence Seaway, and other important structures such as military airfields.

Thermal radiation and absorption studies. Any cool material exposed to the sun will absorb heat and, as its temperature increases, will radiate heat more rapidly until its reaches a temperature at which radiation and absorption rates are equal. This steady temperature is different for different materials; hence the temperature in a space vehicle can be controlled by selecting surfacing materials with the desired absorbing and radiating properties. Automated equipment for measuring radiation properties of materials has been developed at NBS, and standard specimens for calibrating apparatus in other laboratories are being prepared.

Heat transfer studies. The broad objectives of heat transfer studies at NBS are (a) to develop methods and make measurements on selected materials for providing accurate thermal conductivity data for scientific and engineering purposes; and (b) to develop and furnish suitable reference standards for checking or calibrating similar equipment in other laboratories.

Applied Mathematics

Statistical engineering laboratory. The principal function of the NBS statistical engineering program is to advise the Bureau's scientific and technical personnel on the application of modern probability and statistical methods to physical science and engineering experimentation. It also engages in basic research on pertinent topics in the mathematical theory of probability and mathematcial statistics, in the preparation of manuals on selected phases of statistical methods, and

in the construction of tables and other aids to the application of modern statistical methodology.

Computation laboratory. The Bureau's Washington computation facility includes an IBM 1410–7090 computer system which is used to solve problems in the areas of scientific research, business-management applications, and large-scale data processing for NBS and other Government agencies. Examples of the scientific computations performed are problems in the diffusion of gases and reactions in gases, trajectory computations, multilayer adsorption studies, and contour plotting of magnetic fields. Among the important data processing problems have been mortgage loan surveys, tax depreciation revisions, availability of television service by ultra high frequency TV stations, analysis of interhospital differences of effective treatment of patients, and a fallout shelter survey.

Data Processing Systems

SEAC. The SEAC (Standards Electronic Automatic Computer) was, when completed at NBS in 1950, the first internally sequenced digital computer in the United States. Since that time it has been the workhorse for many computational programs. It has been particularly useful because of its wide variety of inputs and outputs, including magnetic tape, punched paper tape, keyboard, and direct optical sensing. Thus it has been found especially valuable in providing versatile computer facilities for exploratory approaches needed for many experiments and has been used in many pioneer programs.

ACCESS. ACCESS (Automatic Computer Controlled Electronic Scanning System) is a computer system for accepting data from microfilmed documents. The computer functions to select the desired parts of the document being scanned at the moment. This scanning is done with FOSDIC V, a direct descendant of the FOSDIC devices used in the decennial Census. ACCESS translates data into binary information and can be programmed to perform a number of computation and translation operations on the data.

AMOS IV. The AMOS (Automatic Meteorological Observation Station) is a device developed by NBS for the Weather Bureau for gathering and transmitting weather data. AMOS equipment is to be located at airports, with the weather condition sensors from which it constantly receives raw data, to transmit processed data via teletype lines to weather centers. The computational circuits calculate representative values of conditions for which instantaneous values are not meaningful, such as wind speed and direction. AMOS also determines, from meteorological measurements and tabular data encoded in its memory, the local runway visual range and approach light contact height for use by aircraft.

Computer processing of photographic images. Normally, numerical data rather than pictorial matter are encoded in digital memories, but a technique for pictorial input has proved to be useful in several research projects. Microscopic photographs of alloys in which one metal is present as inclusions or "islands" in the other have been scanned by a photoelectric device and placed into the machine memory as equivalent black and white patterns. This has made possible new techniques for metallurgical and biological analysis.

Engineering applications. Much of the NBS data processing systems work is performed for other Government agencies. Many devices of specialized nature, ranging from a computer program for simulating city traffic flow to a radioactive fallout predictor, have been developed. Computer-type devices have been developed to simulate systems of which man is a part, such as air-traffic control, for experimentation on man-machine relations to obtain maximum safety and efficiency.

PILOT. The initial PILOT data processing system is now in operation, but is already being readied for expansion. It will be a particularly versatile tool for use as a "computer for simulating other computers" to determine the preferred way of using features available on other computers.

Atomic Physics

Atomic spectroscopy. Spectrographs mounted in high-altitude rockets gather data on portions of the solar spectrum at wavelengths absorbed by the earth's atmosphere. Satellites, now planned, will also bring back spectrograms of the sun and other stars. Not all the spectral features observed in these flights can be identified and evaluated at the present time because wavelength standards in this region are not available and some of the lines on the spectrograms have never been observed previously. NBS has recently placed in operation a 35-ft vacuum spectrograph specifically designed to operate in the region of the spectrum from 500 to 2000 Å. This instrument will aid in the basic research necessary to establish the wavelength standards with which the astrophysical data now being obtained can be interpreted.

High-resolution infrared spectroscopy. Most industrial laboratories and many chemical and biochemical research laboratories employ infrared spectrometers to identify and study chemical compounds. These spectrometers must be accurately calibrated. The NBS high-resolution infrared spectrometer has been used to measure very accurately the absorption bands of a number of common substances. Another very important phase of work performed with this instrument involves the precise characterization of the size and shape of different molecules.

Vacuum ultraviolet radiometry—synchrotron light. Accurate and reproducible measurement of radiation intensities in the far ultraviolet region of the spectrum is a prerequisite to progress in a number of important fields. These include plasma physics, laboratory spectroscopy, photochemistry, and the study of the interaction of far ultraviolet radiation with solids and solid surfaces. Radiometric standards in this spectral region are in great demand, especially for absolute calibration of ultraviolet flux measuring devices carried above the earth's ozone layer in rockets and satellites to study

the ultraviolet albedo of the earth's atmosphere, the ultraviolet solar spectrum, and the ultraviolet spectra from other stars. The NBS 180-Mev synchrotron is being studied as a potential radiation standard in the far ultraviolet spectral region. Detailed calculations show that the highly polarized continuum emitted by these electrons has a unique application in physical experiments. The ultilization of this synchrotron radiation in absorption spectroscopy recently led to the discovery of new atomic energy levels in helium, neon, and argon.

Electron paramagnetic resonance. Paramagnetic resonance is a technique used in solid-state physics to study defects and "impurities" in crystals. The technique also has an important application in the amplification of microwave radiation in a maser. Most maser studies have been made on ruby, an aluminum oxide containing a very small amount of chromium. The experiment shown was the measurement of the microwave spectrum of molybdenum in rutile (TiO_2), also a popular maser substance.

Electron microscope observations of silicon. The sharpness of electron micrographs of metals is strongly affected by inelastic scattering of the electron beam. The picture may, in some cases, be blurred as a result of this effect; in others, contrast can be intensified by the proper use of inelastic scattering. The pictures taken with this instrument are used to measure several important physical quantities, including scattering angle and mean free path.

Plasma spectroscopy. Nearly all the scientific information that we have on the sun and other stars is obtained from studies of the spectral lines emitted or absorbed by the hot gases surrounding the star. The intensities of the lines observed lead to the determination of such characteristics as the temperature of the star and the density of atoms in its atmosphere, provided the absolute line strengths are known. These absolute line strengths can be found by studying carefully controlled plasmas of the same hot gases. In addition to their application to the interpretation of astronomical data, these line strengths help in characterizing manmade hot gases found in nuclear fusion and high-velocity shock tube experiments.

Instrumentation

Electronic fault location techniques. Many electronic systems used in the defense of this country must be maintained at peak efficiency, but this is costly and difficult because of their complexity and the scarcity of highly skilled technicians. Fault-locating equipment being developed at NBS will enable semi-skilled maintenance personnel to locate the module causing trouble in electronic equipment.

Semiconductor device studies. Transistors are but one of the group of semiconductor devices which is being widely used in both civilian and military electronic equipment. So many new types are being produced that a coordinated study of the physics of semiconductor materials is needed. NBS is conducting this study with the cooperation of the American Society for Testing and Materials, the American Standards Association, the Joint Electron Devices Engineering Council, and semiconductor manufacturers.

FOSDIC. The Bureau of the Census prepared for its 1960 decennial census by automating the most time-consuming and costly steps in handling the data obtained by its nearly 160,000 enumerators. NBS developed FOSDIC (**F**ilm **O**ptical **S**ensing **D**evice for **I**nput to **C**omputers) to translate the markings on nearly 50,000,000 sheets of paper into a form suitable for computer input. The machine demonstrated is FOSDIC IV, which translates 2 million bits of information per minute from microfilmed punched cards to magnetic tape. This machine will be used by the Weather Bureau to select past weather data contained on microfilm for computer input.

Transducer laboratory. Much of our information about the operational characteristics of missiles is obtained by telemetering back to ground information on the missile—its displacement, acceleration, and skin temperature, for example. Such information is received by a pickup unit, or transducer. Several Government agencies depend upon the Bureau's analysis of transducer performance to evaluate their own units. In some instances adequate test methods have not been developed and the testing scientists must first adapt or improve existing test equipment and techniques. Tests of electromechanical transducers include measuring responses of pressure transducers to a pressure-step generator and acceleration of transducers mounted on a vibrating platform. The results of such tests are used by the participating agencies as a basis for selection, to point the way to improved design, and to permit measurement standardization.

MICROCITE. The Office of Basic Instrumentation is responsible for collecting and cataloging up-to-date information on test instruments. Microcite, a device for making rapid searches through a body of information, was developed to facilitate this program. It permits the operator to select for inspection abstracts of approximately 18,000 referenced documents.

Physical Chemistry

Calorimetric measurements. Calorimetric measurements offer a means to determine accurate values of certain thermodynamic properties, such as the heats of formation. The compilation of data on the thermodynamic properties of chemical substances is greatly needed in (a) the development of propellants, explosives, and fuels for the defense effort; (b) the development of industrial processes involving chemical reactions; and (c) fundamental research on the physical and chemical behavior of materials.

Field emission studies of metal surfaces. Field emission microscopy is a technique for observing surfaces on a molecular scale. A field emission microscope, operated at liquid helium temperatures, is being used in this laboratory to study the interaction of molecular and atomic hydrogen with metal surfaces. The microscope tube is attached to an apparatus in which a beam of atomic hydrogen is directed onto the surface of a

tungsten field emitter, a single hemispherical tungsten crystal with a radius of 0.00002 in. The image of the surface, magnified about 100,000 times, shows details of the surface arrangement of the hydrogen adsorbed on the surface. In operation, the pressure in the microscope tube is less than one millionth of a billionth of atmospheric pressure.

Carbon 14 and tritium-labeled compounds. In this laboratory, methods are developed for the synthesis of radioactive sugars. These sugars contain either carbon 14 or tritium at specific positions in the molecule, and are used as tracers in chemical and biological research. Compounds prepared in this laboratory have been furnished to many scientific laboratories and to the majority of medical schools in the country.

Cryogenic spectroscopy. This research involves the rapid freezing and isolation of reactive molecules at extremely low temperatures in order that their spectra can be studied without fear of further decomposition or reaction. This means that it has been possible to investigate molecular species which have very short lifetimes or which exist only at extremely high temperatures.

Shock tube kinetics. The understanding and control of many processes of technological importance (e.g., combustion, high-energy radiation treatment) depend ultimately on a knowledge of the nature and rates of the elementary reactions that result in overall chemical change. In most cases, the overall processes are very difficult to analyze into their component steps. Development of methods of investigation of these separate steps is one of the important tasks of kinetics. The single-pulse shock tube offers a means for isolating and studying single-step reactions or molecular collisions without interference from secondary processes.

Photoionization laboratory. Gaseous ions play a significant role in many areas of our technology. In radiation technology, many of the chemical changes brought about by high-energy radiation involve ionic intermediates. In space technology, one of the potential means of propulsion involves the production and acceleration of ions. Further, outside the lower reaches of the earth's atmosphere, the solar radiation is energetic enough to produce ionization. In order to understand and exploit these phenomena fully, it is necessary to have detailed information on the nature of these ions, their energy content, modes of formation, and behavior. In this laboratory, these questions are studied by means of photoionization techniques. Ions are produced by irradiation of molecules with light in the far ultraviolet region. Their energetics are studied by varying the wavelength of the light, and their behavior by determining their mass-to-charge ratio in a mass spectrometer.

Photochemistry and radiation chemistry of small molecules. The manner of decomposition of molecules when subjected to ultraviolet and gamma-ray radiation is being studied in the gas, liquid, and solid phases. The exhibit showed equipment used to irradiate molecules at very low temperatures. Gas chromatography and mass spectrometry are used in the analysis of the products.

Goggle-eyed visitors watch oxide single crystals being grown in a furnace at extremely high temperatures.

Office of Weights and Measures

The industry and business of the nation, as well as all consumers, depend daily upon the accuracy of weights and measures of materials, commodities, and services purchased or sold. Although the individual States have regulatory authority in weights and measures, the values of their basic standards and the basis for many of the technical procedures involved in weights and measures regulation emanate from the NBS Office of Weights and Measures.

Radio Standards Laboratory

Frequency and time interval standards (special display by NBS Boulder, Colo., Laboratories). Time and its reciprocal, frequency, can be measured with greater precision than can any other physical quanity. The unit of time, together with the units of mass and length, is the basis upon which many of the units of our measuring system are formed. Highly precise measurements of time are necessary for the navigation of ships and planes and the tracking and control of rockets and satellites. By matching the frequency of electronic oscillators to the natural frequencies of atoms, a standard of frequency has been constructed affording precise measurements to one part in a hundred billion. By counting the cycles of such oscillators, a time scale can be constructed which is more than one hundred times as uniform as the earth's rotation. These highly precise standards of frequency and time interval are made immediately available to users by radio broadcasts from NBS stations WWV, WWVB, WWVL, and WWVH.

Low-Temperature Infrared Spectroscopy Of Inorganic Carbonates and Nitrates

LOW-TEMPERATURE measurements of the infrared spectra of selected single crystals of anhydrous nitrates and carbonates have recently been completed at the Bureau. In a study [1] of the effect of temperature changes on the crystal form and on molecular interaction in solids, R. A. Schroeder, C. E. Weir, and E. R. Lippincott have attributed certain bands in the complex infrared spectra to libration-vibration combinations.[2] The libration is considered to represent a planar torsional oscillation of the anion (e.g., NO_3^- or CO_3^{--}) about the trigonal axis.

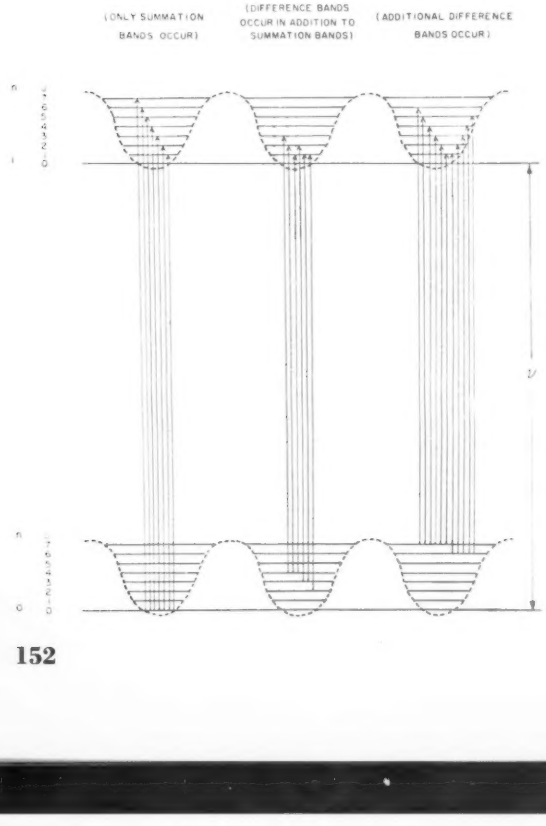
Infrared spectra of the inorganic nitrates and carbonates are believed to be well understood as far as the assignment of the six fundamental vibrations of the free nitrate and carbonate ions are concerned. However, the spectra also have strong overtone and combination bands and show a complexity which has not been completely explained. This complexity has been the subject of several recent studies, some of which were carried out at temperatures as low as that of liquid nitrogen. In the present investigation, even lower temperatures, i.e., liquid helium temperatures, were used in order to improve the resolution of the spectra and to eliminate certain bands.

The following nitrates were studied: $NaNO_3$, KNO_3, $RbNO_3$, $CsNO_3$, $TlNO_3$, $AgNO_3$, $Sr(NO_3)_2$, $Ba(NO_3)_2$, and $Pb(NO_3)_2$. Carbonates studied were: $MgCO_3$, $CaCO_3$, $SrCO_3$, $BaCO_3$, $PbCO_3$, $FeCO_3$, and $MnCO_3$.

Most of the infrared spectra were recorded on a commercial double-beam spectrometer using sodium chloride optics. To provide greater resolution in the overtone and combination regions at frequencies above 1700 cm^{-1}, the sodium chloride optical system was replaced by a grating system. The spectrometer was equipped with a microfocusing unit employing reflecting optics to permit the study of small, thick (about 0.010 in.) single crystals. The unit was further modified for low-temperature work so the tip of the Dewar could be introduced into the focal region.

Five crystals could be studied in a single experiment. The specimens were mounted on a flat plate holder over holes located in two rows staggered so that a single hole could be brought into the focal spot with no stray radiation through the adjacent holes. In a given experiment spectra were recorded at room temperature and then at liquid nitrogen temperature. If the runs at liquid nitrogen temperature proved successful, spectra were then taken at liquid helium temperature.

The diffuse absorption observed in the room-temperature spectra between about 1400 cm^{-1} and 700



Energy level diagram illustrating the effect of temperature on libration-vibration combination bands. In a recent study of the infrared spectra of inorganic carbonates and nitrates, NBS scientists attributed certain bands to libration-vibration combinations, the libration representing a torsional oscillation of the anion (NO_3^- or CO_3^{--}) about the trigonal axis. The diagram shows two vibrational levels: the ground state $n=0$, and the first excited level, $n=1$. In each vibrational level are 7 librational levels, $J=1$ to $J=7$. Transitions between energy states, indicated by vertical lines, arise from combinations of the librational frequency with fundamental vibrational frequencies. These combinations may be sums or differences of the frequencies. At very low temperatures (liquid helium) when all the ions are in the lowest librational state, only summation bands are possible. At intermediate temperatures, in addition to summation bands, some difference bands arise from the thermal excitation of some ions of the ground vibrational level into the lower librational levels. At higher temperatures, in addition to the previous transitions, additional difference bands arise from thermal excitation to higher librational levels in the ground vibrational state.

Specimen holder used in a recent NBS study of the low-temperature infrared spectra of inorganic carbonates and nitrates. Results show that certain bands in the complex spectra may be attributed to combinations of libration and vibration of the anions. The copper holder plate is ½ in. square, ⅛ in. thick, and the total length is 2 in.; the holder fits on the tip of the liquid reservoir of a Dewar. The crystals were mounted in a shallow well on a flat web of copper. The infrared beam is focused so that a single hole can be brought into the focal spot with no stray radiation through adjacent holes.

Charles E. Weir observes the recording of spectra with the low-temperature apparatus utilizing a Dewar (*right*). The spectrometer is equipped with a microfocusing unit (*right front*) employing reflecting optics to permit the study of small, thick single crystals. The crystals are mounted on a special holder enclosed in a housing containing windows to pass the infrared radiation and the entire system is evacuated.

cm^{-1} was resolved at liquid helium temperature into a series of a large number of bands not attributable to fundamentals or to combinations between fundamental frequencies of the anions. However, the combination of a fundamental frequency with a specific low-lying frequency gave sum and difference bands, located symmetrically on either side of the fundamental, provided the temperature was sufficiently high. At room temperature the diffuse absorption arising from these bands is quite obvious. At liquid nitrogen temperature the intensity of the difference bands (on the low frequency side of the fundamental) is reduced and at liquid helium temperatures the difference bands have disappeared. As predicted from a consideration of the energy levels, the summation bands are not removed by temperature changes.

The low-lying frequency which combined with the fundamentals was found to be of the order of 20 cm^{-1} to 30 cm^{-1}. All the structures studied, both carbonates and nitrates, gave a spectrum in which a frequency difference of this order (20 cm^{-1} to 30 cm^{-1}) appeared, independent of the inorganic cation. These materials have one common characteristic—each contains a planar anion having trigonal symmetry—and it appears that the recurring frequency difference should be attributed to a librational motion of these anions, i.e., a torsional oscillation about the trigonal axis. Such a libration would be expected to occur at a frequency determined largely by the interionic potential forces. Since there is evidence that the interionic forces in these crystals would be of the same general order of magnitude, it seems reasonable to conclude that the low-lying frequency arises from libration of the anions. Further experiments are required to determine whether this behavior is restricted to carbonates and nitrates.

[1] *For further technical details, see* Lattice frequencies and rotational barriers for inorganic carbonates and nitrates from low temperature infrared spectroscopy, *by R. A. Schroeder, C. E. Weir, and E. R. Lippincott, J. Res. NBS* **66A** *(Phys. & Chem.), 407–434 (1962).*

[2] *The term libration is defined as a periodic oscillation or a rocking motion.*

Work Begun on NBS Reactor Buildings

CONSTRUCTION of the buildings that will house the NBS reactor and associated laboratories at Gaithersburg, Maryland is well underway. Excavations have been completed, and pilings for support of the hot cells and the reactor building have been installed. The concrete foundation for the reactor building has been poured, and work will soon begin to erect its outer walls.

The General Services Administration, which is responsible for the construction program, recently awarded a $5 million contract for this phase of the work to the Blount Brothers Construction Co., of Montgomery, Ala. The reactor complex will be used to advance the measurement, analysis, and understanding of radiation effects on substances of all kinds. It will be shared with other Government agencies in the Washington area having the same general requirements as the Bureau.

The high-flux research reactor, to be known as the NBSR, will enable the Bureau to fulfill its growing responsibilities in the many rapidly expanding fields of atomic energy. Reliable precision measurement techniques and standards for high- and low-energy neutron fluxes are urgently needed in various areas of scientific and applied research, such as radiation effects and instrumentation.

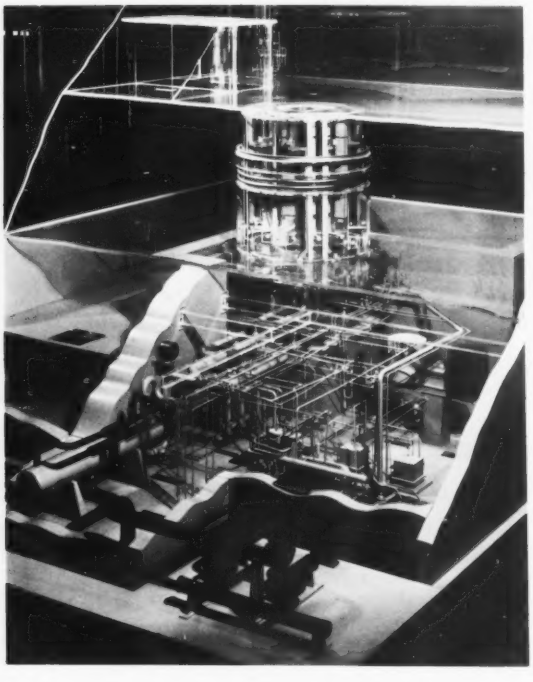
Perhaps the most significant function of the NBSR will be its use in studying certain fundamental properties of matter by neutron diffraction. Fission is of particular importance among the basic processes to be studied, as inadequate understanding of this process and insufficient information on neutron yields limit the design of fissile material breeding plants.

An important aspect of the reactor facility construction is the tightness of the containment building which houses the reactor proper. This building, including its many penetrations (doors, piping, conduits, etc.), must be so constructed that when completely closed off it will not leak air out or in at a rate exceeding 24 standard cubic feet per minute per inch of overpressure or underpressure, respectively. This tightness may also be given in terms of a characteristic building relaxation time, which for the 600,000 ft^3 volume in question would amount to 64 min.

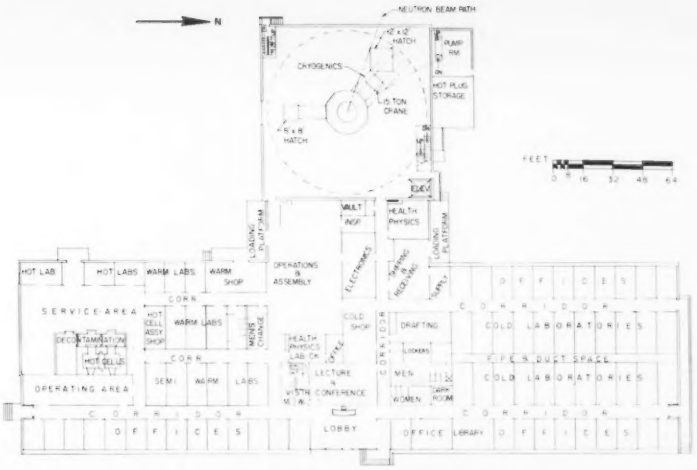
This specification as to tightness has to date been met by only one other reinforced concrete containment structure—the building which houses the University of Buffalo reactor. The techniques required to achieve such a structure have thus been proved feasible, but require the exercise of unusual care during construction. For example, each pour should be pressure-tested, and each penetration should be carefully sealed and tested at the time of installation. The final step to achieve the required tightness is to apply successive elastomeric coatings to the interior wall surfaces until a total dry sealant film thickness of approximately 25 mils is attained. At the completion of this stage of the work and after all heating, ventilating, and air-conditioning equipment has been installed, the NBS staff will assist the contractor in performance tests that must demonstrate the tightness specified.

The NBSR will be similar to the CP 5 reactor at Argonne National Laboratory in that it will be a tank-type reactor using enriched fuel and heavy water moderator. A unique feature is its 24 fuel assemblies, composed of uranium-aluminum alloy clad with aluminum, which will have two active portions separated by a dummy aluminum inactive section. This construction permits continuous coolant flow along the entire length of the assembly, but eliminates fuel in the central plane of the pile. The fast neutron and gamma-ray components emanating from the horizontal beam ports are thereby reduced.

Specially constructed converter fuel elements will provide space for instrumented samples to be irradiated by fast neutrons. In at least one of these regions, cryogenic equipment will maintain near-liquid-helium temperatures during sample exposure.



Scale model of the high-flux reactor—the NBSR. In addition to the usual beam holes and thermal column, the system contains a special cold neutron facility to be used for a variety of neutron inelastic scattering experiments on crystalline and other materials. The fuel elements were designed to have an unfueled section in the region where the horizontal beam tubes view the core. This arrangement eliminates the fast neutrons which give rise to troublesome background in outpile thermal neutron experiments. The model was constructed to a scale of 1/16 in./ft. The processing equipment and associated piping are in the lower foreground, with the cylindrical reactor core above. At the top left is the control room.



Plan view of the building, to be constructed at Gaithersburg, Md., that will contain the Bureau's high-flux research reactor.

A special in-pile cold neutron moderator is planned so that scientists can conduct a variety of neutron inelastic scattering experiments on crystalline and other materials. Current studies of the neutron slowing-down process will provide information pertinent to the design of this facility.

Present plans call for 24-hr operation of the reactor. The initial operating level will approach 10 Mw; fixed features will be designed to permit operation at 20 to 25 Mw when additional cooling towers and heat exchangers are added. The initial operating power will provide an in-pile flux of 10^{14} neutrons/cm^2/sec.

U.S., U.S.S.R. Exchange Measurement Experts

EARLY IN JUNE, a seven-man team of measurement experts from this country traveled to Russia for a month-long tour of various measurement laboratories.[1] Later in the year a similar team of Soviet metrologists will make a visit to the United States. These visits are being conducted under the terms of a United States-U.S.S.R. agreement for the interchange of information and the exchange of visits by teams in 13 fields of technology. The U.S. State Department, under whose general control the exchange program is conducted in this country, requested that NBS arrange for the exchange of persons from the area of high-precision measurement standards.

The American team, headed by William A. Wildhack, Associate Director of the National Bureau of Standards, was comprised of members representing various areas of the measurement field. The others on the team were L. Guildner, F. K. Harris, D. P. Johnson, H. Lance, and A. G. McNish of NBS, and G. Toumanoff of the Airborne Instruments Laboratory, Long Island, New York. Mr. Toumanoff, in addition to being a measurement expert, is fluent in the Russian language.

While in the U.S.S.R., the American group visited installations in Moscow, Leningrad, Kiev, and Kharkov, including laboratories specializing in pressure, length, temperature, electrical, and many other types of measurements. A preliminary itinerary for the Soviet visit later this year includes stops at NBS Washington and Boulder, Colo., a state weights and measures office, and an industrial calibration laboratory.

This exchange is but one of many taking place between the two countries. The general provisions for such exchanges are set forth in an agreement signed by representatives of both nations in March 1962. This agreement, the third of a continuing series, provides for exchanges in the fields of science, technology, construction, trade, agriculture, and many others.

[1] *A full report of the trip will be delivered by the team at the Instrument Society of America meeting in Chicago, September 9 to 12. A summary of the report will appear in a later issue of the Technical News Bulletin.*

Correction

In the story "Humidity Affects Dielectric Properties of Polymers," in the May 1963 TNB, there were two typographical errors. On page 84, under "polyethelene," the second sentence should read "The dissipation factor for polyethelene increased from about **15** (rather than 15) $\times 10^{-6}$ to values as much as 700 to 800% higher, in various cases, and was still rising after 3 years." In the graph of dissipation factor on the same page, the multiplying factor should be $\mathbf{10^{-6}}$ rather than 10^{6}.

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Publications of the National Bureau of Standards

Periodicals

Technical News Bulletin, Vol. **47**, No. 7, July 1963. 15 cents. Annual subscription: $1.50; 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

CRPL Ionospheric Predictions for October 1963. Three months in advance. No. 7, issued July 1963. 15 cents. Annual subscription: $1.50; 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: domestic, $2.25; foreign, $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: domestic, $4; foreign, $4.75.

Current Issues of the Journal of Research

Section A. Physics and Chemistry, Vol. **67A**, No. 4, July–Aug. 1963.

Symmetry splitting of equivalent sites in oxide crystals and related mechanical effects. J. B. Wachtman, Jr., H. S. Peiser, and E. P. Levine.

Relaxation modes for trapped crystal point defects. A. D. Franklin.

A note on the galvanomagnetic and thermoelectric coefficients of tetragonal crystalline materials. W. C. Hernandez, Jr., and A. H. Kahn.

Photolytic behavior of silver iodide. G. Burley.

Correlation of muscovite sheet mica on the basis of color, apparent optic angle, and absorption spectrum. S. Ruthberg, M. W. Barnes, and R. H. Noyce.

Thermodynamic properties and magnesium oxide and beryllium oxide from 298 to 1,200 °K. A. C. Victor and T. B. Douglas.

Heat exchange in adiabatic calorimeters. E. D. West.

Preparation of anhydrous single crystals of rare-earth halides. N. H. Kiess.

A phase study of the system: oxalic acid/acetic acid/water; its significance in oxalic acid crystal growth. J. Strassburger and J. L. Torgesen.

Wavelength calibrations in the far infrared (30 to 1000 microns). K. N. Rao, R. V. deVore, and E. K. Plyler.

On the fourth order Hamiltonian of an asymmetric rotor molecule of orthorhombic symmetry. W. B. Olson and H. C. Allen, Jr.

Measurement of the thickness and refractive index of very thin films and the optical properties of surfaces by ellipsometry. F. L. McCrackin, E. Passaglia, R. R. Stromberg, and H. L. Steinberg.

Color phenomena associated with energy transfer in afterglows and atomic flames. A. M. Bass and H. P. Broida.

Section D. Radio Propagation, Vol. **67D**, No. 4, July-Aug. 1963.

Influence of the lower ionosphere on propagation of VLF waves to great distances. J. R. Wait.

Comments on a paper "Auroral sporadic-*E* ionization" by Robert D. Hunsucker and Leif Owren. J. M. Bullen and G. A. M. King.

Reply to J. M. Bullen and G. A. M. King's "Comments on a paper 'Auroral sporadic-*E* ionization' by Robert D. Hunsucker and Leif Owren." R. D. Hunsucker and L. Owren.

Optimum reception pattern of the Beverage wave antenna at very low frequencies. E. W. Seeley.

Effect of a dissipative medium of finite size on antenna measurement. K. Iizuka and R. W. P. King.

Some implications of aircraft interference patterns in tropospheric scatter reception. J. A. Bradshaw.

Asymptotic behavior of the current on an infinite cylindrical antenna. K. S. Kunz.

A dipole approximation of the backscattering from a conductor in a semi-infinite dissipative medium. M. B. Kraichman.

Small electric and magnetic antennas with cores of a lossy dielectric. J. Galejs.

Nonperiodicals

Refractive indices and densities of aqueous solutions of invert sugar, C. F. Snyder and A. T. Hattenburg, NBS Mono. 64 (June 7, 1963), 15 cents.

Reduction of data for piston gage pressure measurements, J. L. Cross, NBS Mono. 65 (June 17, 1963), 15 cents.

Tabulation of data on receiving tubes, C. P. Marsden and J. K. Moffitt, NBS Handb. 83 (May 23, 1963), $1.25. (Supersedes Handb. 68.)

Table of attenuation error as a function of vane-angle error for rotary vane attenuators, W. Larson, NBS Tech. Note 177 (May 20, 1963), 75 cents.

Tabulation of published data on Soviet electron devices, C. P. Marsden, NBS Tech. Note 186 (June 3, 1963), 45 cents.

Tables describing small-sample properties of the mean, median, standard deviation, and other statistics in sampling from various distributions, C. Eisenhart, L. S. Deming, and C. S. Martin, NBS Tech. Note 191 (June 14, 1963), 20 cents.

National standard reference data program, background information, NBS Tech. Note 194 (June 1963), 25 cents.

Publications in Other Journals

This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

Nuclear magnetic resonance in metal powders at low temperatures, R. J. Snodgrass and L. H. Bennett, J. Appl. Spectry. **17**, No. 2, 53–54 (1963).

Millimeter wavelength resonant structures, R. W. Zimmerer, M. V. Anderson, G. L. Strine, and Y. Beers, IEEE Trans. Microwave Theory Tech. **MTT–11**, 142–149 (Mar. 1963).

Lunar point-to-point communication, L. E. Vogler, Book, Technology of Lunar Exploration, Progress in Astronautics and Aeronautics **9**, 533–559 (Academic Press Inc., New York, N.Y., 1963).

Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.

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